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Analysis of the public transport system in the metropolitan area of Valencia through a discrete choice model. Proposals to improve and integrate the fare structure.

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Abstract

This document intends to propose a solution to one of the main mobility problems of the metropolitan area of Valencia: the lack of integration and rationalisation of the public transport network and its fares. With a region that has developed rapidly over the last decades, public transport modes do not constitute an attractive and practical solution over private vehicles and the metropolitan citizens tend to favour this last option. Therefore, the document will give a global overview of the context of mobility in the metropolitan area, identifying the main modes, costs and trends, and will explain which factors lead potential users to decide between them by means of a discrete choice model. This tool will allow to assess several variables and their sensitivity, finding out the most relevant. The final objective will be to propose new scenarios that modify the current fare structure, thus acting on costs, the most influential variable. All alternatives proposed will be compared to determine their potential implementation. Finally, the document will evoke possible areas of action for future improvements and, in view of all the results, will share some conclusions.

Résumé

Ce document vise à proposer une solution à l'un des principaux problèmes de mobilité de l'aire métropolitaine de Valence : le manque d'intégration et de rationalisation du réseau de transport public et des tarifs. Avec une région qui s'est développée rapidement au cours des dernières décennies, les modes de transport en commun ne constituent pas une solution attractive et pratique par rapport aux véhicules privés, c'est pourquoi les usagers ont tendance à privilégier cette dernière option. Le document donnera un aperçu global du contexte de la mobilité dans l'aire métropolitaine, en identifiant les principaux modes, coûts et tendances, et expliquera quels facteurs conduisent les utilisateurs potentiels à décider entre les modes grâce à un modèle à choix discret. Cet outil permettra d'évaluer plusieurs variables et leur sensibilité, en trouvant les plus significatives. L'objectif final sera de proposer plusieurs scénarios qui modifient la structure tarifaire actuelle, agissant ainsi sur les coûts, l'une des variables les plus significatives. Toutes les alternatives seront comparées pour déterminer leur mise en place potentielle. Enfin, le document évoquera les possibles pistes d'amélioration et, au vu de tous les résultats, partagera quelques conclusions.

INDEX

LIST OF FIGURES

LIST OF TABLES

I. Introduction

Mobility in metropolitan areas is one of the main organisational challenges of the current urban societies. People have the need to move in their daily lives (demand), which should be organised and managed preferably in a collective way (supply). This is done to avoid individual decisions that would lead to the saturation of transport infrastructures, with all the direct consequences and externalities that this would entail.

In our cities and in their surroundings, the main limiting factor to mobility is the lack of space available. More than half of the urban public space is currently oriented towards the use of private vehicles and their transit, while the total percentage of journeys and travellers does not meet these numbers. This public space is, therefore, used in an inefficient way and could be reorganised for other uses if a greater collectivisation of the individual transport demand is achieved. This is why political bodies at a local and at a regional level have gradually created a dense network formed by several means of public transport, such as buses, commuter trains, subways or tramways, to serve the people living in large cities and their metropolitan areas.

The current way of life has multiplied the number of destinations and reasons why citizens move. As opposed to the unimodal displacements that prevailed in the past, current travellers make a greater number of journeys and use more modes, including transfers if necessary. Hence, a good coordination among all transport operators is required, which allows these multimodal journeys to take place. It is essential that users are not affected by unconnected and individual tariffs depending on the mode, which lead to higher costs for them and less attractiveness of the service at the metropolitan level. An efficient and quality collective transport network should be one that has sufficient flexibility to adapt to the interconnections that its users are willing to make without this having an excessively high monthly cost for them.

One could think that these public services are financed by the incomes generated by the tickets and plans, validated by the users when they access the network. Nevertheless, operational costs are much more important than what the incomes represent and will require being complemented with additional monetary contributions from other sources. Both in Spain and in other European countries, the different levels of the government contribute to the sustainability and to the development of the public transport network.

On the one hand, the Spanish legislation states that urban transport and mobility are two competences regulated by the local entities/municipalities (Law

7/1985 from April 2nd, 1985, *Ley Reguladora de las Bases del Régimen Local*) [1]. This law establishes that every municipality with a population that exceeds 50,000 inhabitants must have a mass urban transport system for passengers. At the same time, autonomous communities (the second administrative level, below the national state, corresponding to the regions in Spain) can assume, if the corresponding Statute of Autonomy says so, the competences in railway, road or cable transportation, if this takes place entirely within the domain of the autonomous community [2].

On the other hand, the European Union has stated that financing the urban public transport network is also a responsibility of the national states and not only of the regional/local entities. Consequently, all levels of the Public Administration should cooperate when designing a system that allows to cover the network costs as much as possible, while at the same time effectively reducing the cost for users without affecting the level of service provided.

The first steps have already been taken, with an initial coordination effort of the different operators creating integrated transport fares. This is the case of Valencia, the city under study in this report. The creation in 2017 of the *Autoritat de Transport Metropolità de València* (the Metropolitan Transport Authority of Valencia), under the regional government, has also led to a positive advance in the coordination of urban transport competencies in the metropolitan area. In any case, the current situation is still far from being the definitive solution that was originally conceived, as there are some aspects to consider in order to reach this optimal horizon.

i. Scope and objectives

The problem to be analysed in this document stems from the previous facts and will focus on metropolitan mobility and the integration of the different services: how should the metropolitan public transport network in Valencia change in order to provide a more attractive option if compared to the use of private vehicles?

To achieve this, the document will begin with an introductory description of the current state of mobility in that city, also using comparative elements with other similar cities. Special emphasis will be placed on the characterization of existing public transport modes and the interconnections between them. Next, the state of the art will be described in terms of zoning and tariffs in intermediate cities, nationally and internationally. Moreover, the current situation will be analysed based on the information provided by the Metropolitan Mobility Plan (*Plan Básico de Movilidad del Área Metropolitana de València*, or PMoMe), determining a discrete choice model that allows to explain the modal distribution between public transport modes and private vehicles, as well as defining an average rate for the collective modes. Based on the results, several scenarios of modification of the tariff structure –leading to greater integration in the system- will be tested. Once the proposals have been determined, the consequences and impacts derived from their implementation will be analysed, finalising with a series of conclusions.

The ultimate objective of the report will be to offer a lower average tariff than the current one, while at the same time favouring the integration of the public transport system, thus enhancing multimodality, increasing the demand for public transport and, ultimately, a better coordination between the different operators.

ii. Geographical area

The geographical scope of this document must be clearly defined. It will be the one that is specified in the PMoMe [3], which subdivides the metropolitan area in circular sectors according to their distance to the capital. These zones are:

1. The city of Valencia, excluding the outer districts of Cases de Bàrcena, El Palmar, El Perellonet, El Saler, Mahuella, Massarrojos, Pinedo and Rafalell-Vistabella.
2. The closest municipalities to Valencia, in which there is almost no rupture of the urban continuity. These are Albal, Alboraia, Alfafar, Benetússer, Burjassot, Catarroja, Godella, Llocnou de la Corona, Massanassa, Mislata, Sedaví, Tavernes Blanques and Xirivella.
3. The first urban ring is limited by the A-7 highway and includes the following municipalities: Alaquàs, Albalat dels Sorells, Albuixech, Alcàsser, Aldaia, Alfara del Patriarca, Almàssera, Beniparrell, Bonrepós i Mirambell, Emperador, Foios, Manises, Massalfassar, Massamagrell, Meliana, Moncada, Museros, Paiporta, Paterna, Picanya, la Pobla de Farnals, Quart de Poblet, Rafelbunyol, Rocafort, Torrent and Vinalesa, as well as the outer districts previously excluded.
4. The second urban ring is located at the other side of the A-7 highway and includes those municipalities that have rapidly grown over the last decades thanks to the improvement of the connections with the capital. These are Alginet, Almussafes, Benaguasil, Benifaió, Benisanó, Bétera, Buñol, Canet d’En Berenguer, Carlet, Cheste, Chiva, Domeño, l’Eliana, Godelleta, Llíria, Loriguilla, Montserrat, Náquera, Picassent, la Pobla de Vallbona, el Puig de Santa Maria, Puçol, Riba-roja de Túria, Sagunto,

San Antonio de Benagéber, Serra, Silla, Sollana, Sueca, Turís, Vilamarxant.

The following image shows the composition and extension of the metropolitan area of Valencia.

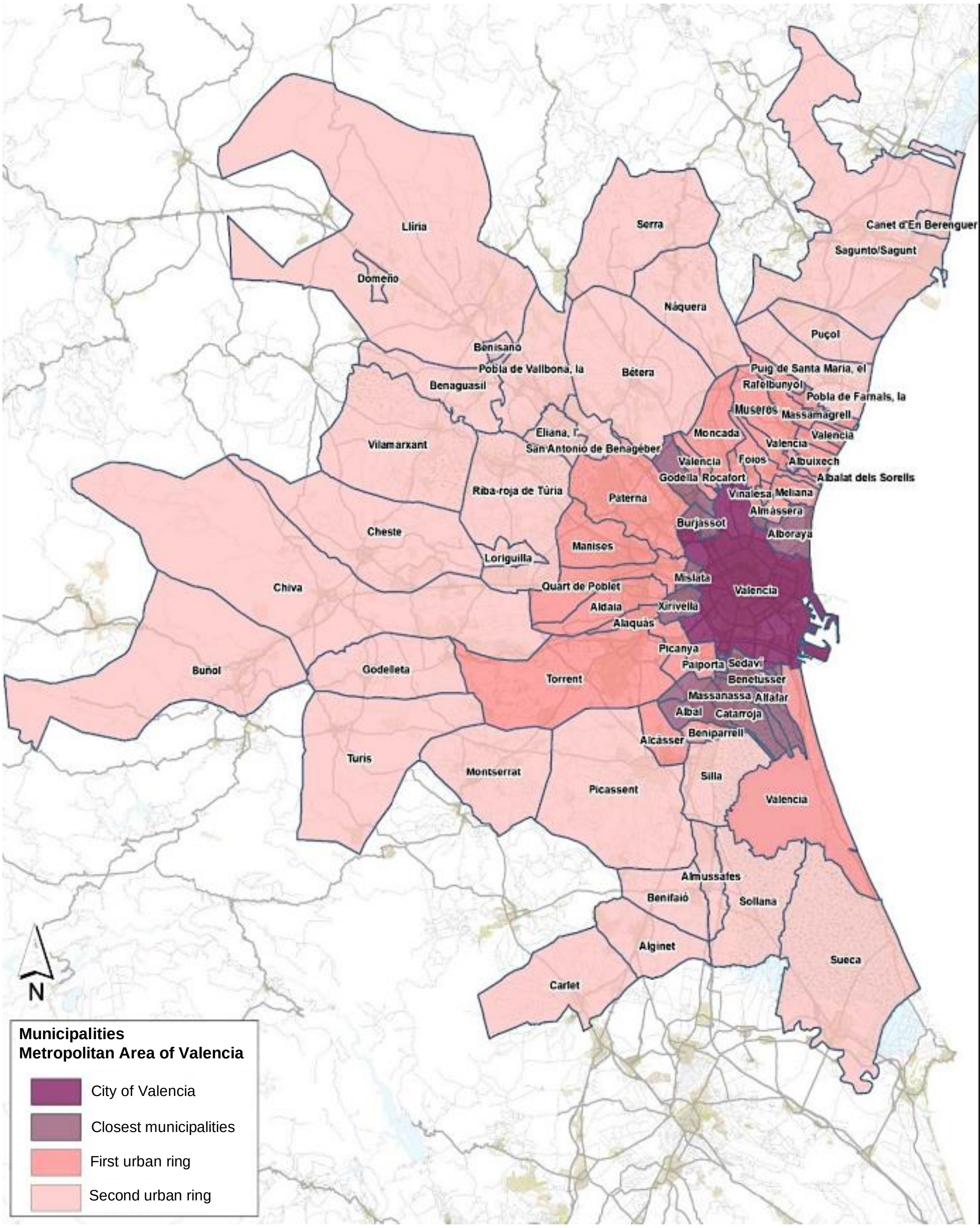

Figure 1. Municipalities conforming the metropolitan area of Valencia. Source: PMoMe (2018) [3].

Nevertheless, we have to highlight that several municipalities (Buñol, Canet d'En Berenguer, Cheste, Chiva, Domeño, Godelleta, Montserrat, Náquera, Serra, Sueca and Turís, all of them in zone D) are still in the process of their effective incorporation to the metropolitan area [4], but have been considered as part of it by the PMoMe. Therefore, they will be considered as metropolitan municipalities to all effects, as they would already be integrated if a hypothetical proposal of this document is eventually implemented.

II. Current mobility context in the metropolitan area of Valencia and comparative analysis with similar cities

The mobility aspects in the metropolitan area of Valencia require a detailed study as they conform a complex situation, with many possible displacements which are commonly interrelated. According to the data included in the PMoMe [3], 12 million journeys take place in the Valencian Community every day, with close to 40% (4.8 million) in the metropolitan area of the capital. This is a clear sign of the importance of this geographic area when compared to the total of the region.

If we analyse these numbers according to the distance travelled, we may see that 28% of the almost 5 million journeys are shorter than 1.5 km, which is a distance that can be easily covered by foot, and 39% are between 1.5 and 5 km, a distance range which is optimal for public transport modes or bicycles. Therefore, more than half of the metropolitan journeys would be specifically indicated for the use of sustainable modes, only considering the distance without any external factors.

Moving on to the data from the Metropolitan Mobility Observatory (*Observatorio de Movilidad Metropolitana*) in their report published in April, 2019 [5], in terms of sustainability of the modal share we may be optimistic with the situation of Valencia. The percentage of displacements carried out by car or motorcycle (31.9%) is one of the lowest from all Spanish large cities, with the sole exceptions of Zaragoza and Leon. Journeys made by foot or by bicycle, favoured by exceptional urban characteristics in terms of climate and morphology, represent almost 45%. Finally, public transport accounts for 23%, quite a significant percentage, mainly boosted by the journeys which take place inside the capital. All of this happens while Valencia has a slightly lower motorisation rate, although this would not explain the difference in terms of use of the private vehicles.

We will now focus on mobility in public transport, which is the basis of this document. The number of journeys per inhabitant and day (2.6) is lower than the Spanish average (around 3) and closer to the largest capitals such as Madrid and Barcelona, but with longer journeys in terms of time and distance. We may highlight the small percentage of multimodal journeys, which represent 5% of the total, far from other Mediterranean cities like Alicante or Barcelona, which exceed 10%. This could be a first indicator of a network that requires improvement in this sense, with systems that operate independently and provide services to their passengers, without being optimised for combinations with the other public modes. This would be the case, for instance, of a passenger who lives in a municipality close to Valencia and who decides to take the train and then uses the urban bus. Operators and fares would not be coordinated in this example.

Also, the passenger load factor is one of the lowest amongst all the main Spanish cities, only higher than in Mallorca, although the data is from 2016 (*Informe Anual del Observatorio del Transporte y la Logísica en España,* 2018) [6]. As a first analysis, this seems to be due to a good offer in global terms, including an important capacity for passengers, whereas the demand would be much lower. This is in line with the previous number of journeys per inhabitant and day.

Therefore, these facts show that the public transport network in the metropolitan area of Valencia has a sufficient (or even more) offer for an urban context of this magnitude, with the exception of the connectivity between the capital and the municipalities without access to the metro or tramway services. The network does not seem to require a change regarding the number of seats offered, but there is still room for improvement in the integration of all modes and levels (urban and interurban) to capture the demand that is currently being lost due to excessive costs or number of fares, lack of attractivity of the service because of long distances and travel times, etc.

In the following sections, we will describe the main collective public transport modes that will be analysed in this document: urban and interurban buses, the metro and tramway system, and commuter trains. This will allow the reader to know better about the current situation of the system and will be necessary to provide an assessment of the metropolitan mobility. Other collective transport modes will be excluded, such as shared transport with vehicles for hire (mainly Cabify in Valencia), the public bicycle sharing system Valenbisi or the electric vehicle sharing systems, such as eCooltra, Acciona or Muving).

i. Urban buses

Urban buses in Valencia are operated by a local public company, *Empresa Municipal de Transportes de Valencia* (EMT), with a total of 56 lines and a discretionary transport service specific to persons with reduced mobility. The network comprises the capital and some of the closest municipalities, such as Alboraia, Alfafar, Alfara del Patriarca, Burjassot, Moncada, Sedaví, Tavernes Blanques and Vinalesa. Out of the 56 regular lines, 12 are night lines. The following image shows the network distribution, which shows a denser grid in the central districts, without crossing the historical centre, and also in the periphery of the capital, then adopting a radial scheme to connect Valencia with some of the closest municipalities [7].

Figure 2. Current urban bus network. Source: EMT Valencia (2020) [7].

Each line has a frequency that is adjusted by EMT according to the time period and to the demand, logically reinforcing the service when there is a greater flow of users. The normal interval in a working day is between 6 and 10 minutes, a range of values which would be acceptable for a city like Valencia. These values increase on Saturdays, Sundays and holidays. This also happens in those lines that have a lower demand and which generally cover journeys to further municipalities. The night service has been recently modified to have frequencies of even 20 minutes, with Valencia also being one of the Spanish cities having a longer working interval of night lines services.

If compared to other cities, we must point out that the Valencian urban buses network has a low line density in terms of number of km and also of stops per 1000 inhabitants, mainly due to the restructuring that took place over the last years. This led to a notable reduction of the amount of km travelled since 2013, a controversial decision which caused the claims to rise due to an apparent lack of service in some districts. The data is updated until 2014, showing a total number of km travelled close to 20.9 million [3].

Despite this, total demand has gone up after the constant declines experimented until 2013, growing more than 12% since that year to reach 96.9 million passengers in 2019 [8]. The network does not seem incorrectly defined in terms of accessibility because, even though the number of stops is low, their spatial coverage is adequate. According to the data from the Sustainable Urban Mobility Plan (SUMP) of the city of Valencia (*Plan de Movilidad Urbana Sostenible de la ciudad de Valencia* [9]), with a radius of 250 metres from each stop, which is equivalent to a 4-minute walk, the spatial coverage of the network is complete.

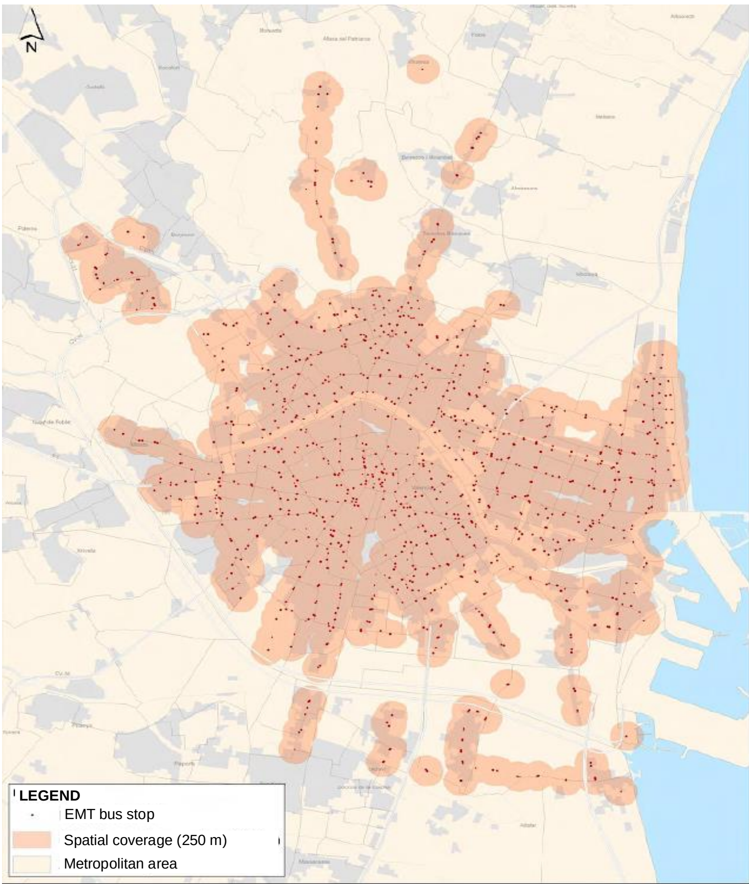

Figure 3. Spatial coverage of the urban buses stops, with a 250 m radius. Source: SUMP of Valencia (2013) [9].

A more precise analysis shows us that the more accessible zones are around the large transit axis in the city centre (streets Colón, Xàtiva and Guillem de Castro), avenues del Port and Aragó, and the streets connecting the centre with the university campus in avenues Blasco Ibáñez and Tarongers. All of these correspond to areas with high passenger transit and demand.

With respect to the bus fleet, over the last year it has experimented a slight increase in the number of units, together with a much needed renovation, as the average age of the vehicles was one of the highest amongst the main Spanish cities. We can highlight the acquisition of hybrid buses in order to reduce emissions of greenhouse gases, which represents an important budgetary effort in the last years but justified as it is in line with the climatic awareness and the objectives of sustainability. However, nowadays the majority of buses are diesel-powered, with obsolete emission standards, which shows that there is still room for improvement.

ii. Interurban buses

Interurban buses in the metropolitan area of Valencia are operated by a group of 7 private companies conforming the MetroBus network. These are Autobuses Buñol, Autobuses Buñol, Autocares Herca, Auvaca, AVSA, Edetania, Fernanbús and Urbetur, according to the regional urban planning and management entity (*Entitat Valenciana d'Habitatge i Sòl*) [10].

The network comprises around 40 lines that connect Valencia with 55 municipalities of the metropolitan area or even between these municipalities. The lines are organised in four concentric zones according to their distance to the capital.

They adopt a radial distribution, corresponding to the main communication routes with centre in Valencia. They also connect the capital with the main commercial malls, industrial sites and technological areas of its surroundings, beyond the urban areas of the municipalities.

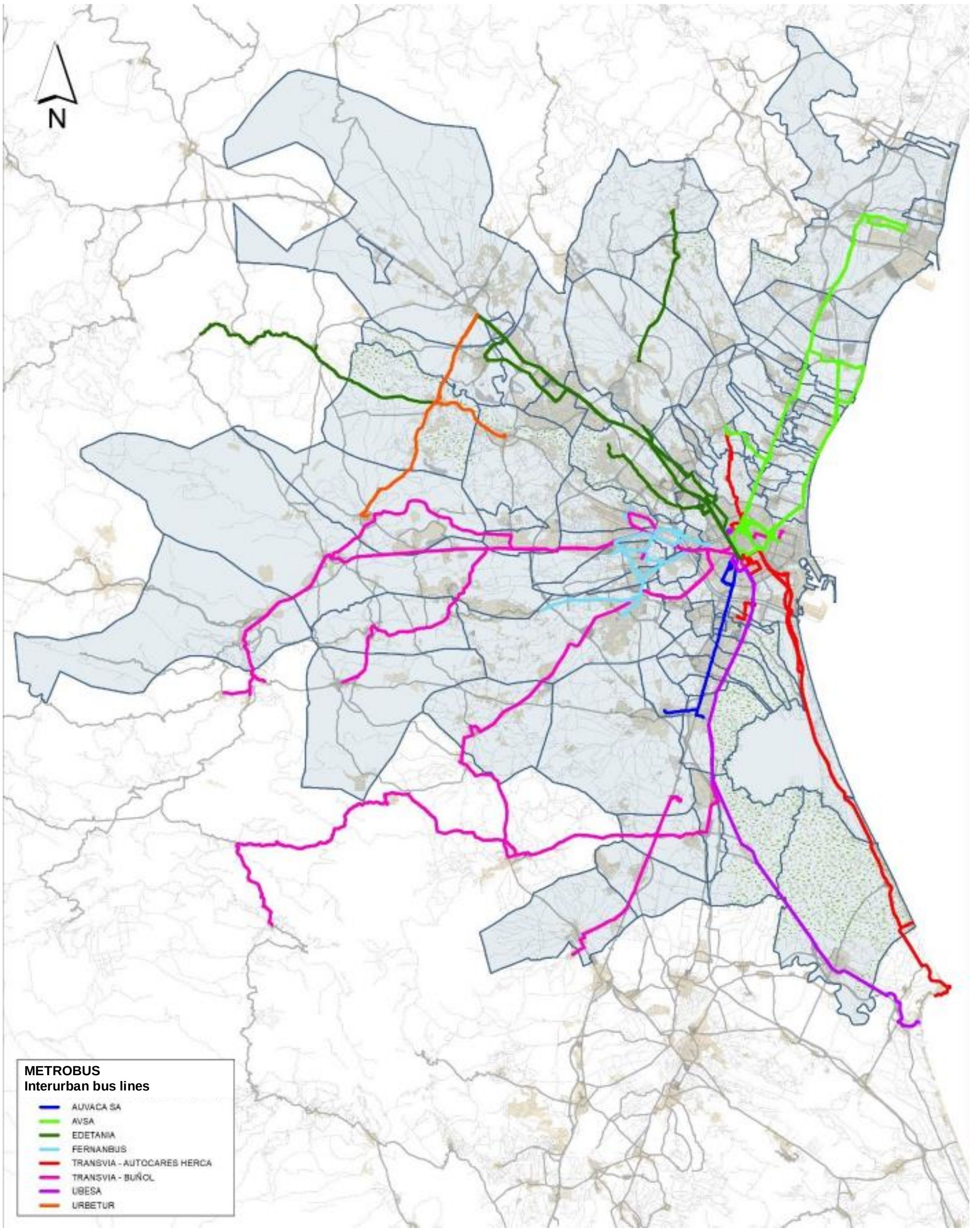

Figure 4. Spatial distribution of the interurban buses lines. Source: PMoMe (2018) [3].

In this case, the line frequencies are clearly longer than those of the urban buses. They also experiment intraday and intraweek variations. Differences between lines are more pronounced, with a greater number of journeys per day in those lines that connect Valencia and the main metropolitan municipalities or the main work centres (for example, Valencia – Catarroja – Albal, Valencia – Puerto de Sagunto or Valencia – C.C. Bonaire) as opposed to those lines with lesser demand or with an alternative public transport mode (for example, Valencia – Riola, Valencia – Moncada or Valencia – El Pouet).

Furthermore, it is important to specify that the hours of operation are generally reduced and the night services are quite limited or directly inexistent. This reduces the possibilities of the users who require to travel to Valencia during these hours, no matter which motives they may have (work, leisure…). In these cases, the predominant mode is the private vehicle.

In absolute terms, the seats per kilometre offered annually in the interurban bus network are significantly lower than those of the other modes, although this could be the main option to vertebrate and connect the metropolitan area. In percentage of the total public transport offer, the low relevance of the interurban buses stands out compared to what happens in Spanish metropolitan areas of similar importance or size (Madrid, Barcelona, Seville, Malaga...). The seats per kilometre offered are even inferior to those in smaller Spanish cities, although the area to be served is greater. The number of vehicles in circulation also seems low. The PMoME indicates that this mode represents 7.7% of the total public transport (the latter being 13.6% of all displacements), so, over the total number of journeys, it only represents around 1%. Crossing this data with those of the average journey by metro and tramway, we can conclude that a part of the demand for interurban transport is absorbed by this other transport mode and that, probably, the rest is captured by private transport, due to the limited attractiveness and offer of the interurban buses [3].

iii. Metro and tramway

Metro and tramway services are managed by the public company Ferrocarrils de la Generalitat Valenciana (FGV) since 1986, when the process of transferring these competences from the Central State Administration to the Autonomous Government ended. FGV, through its commercial brand Metrovalencia, operates passenger transport and manages the infrastructure of the underground and tramway lines in the metropolitan area of Valencia.

The network consists of 9 lines in operation and 1 under construction, with the completion of its first phase planned to conclude in 2021. Out of the 9 lines in operation, 6 are metro lines (underground in the city centre) and 3 correspond to the tramway (L4, L6 and L8). The network comprises 156 km, with 27 km being underground in tunnels and 129 km being above ground. It has a total of 138 stations and stops (35 underground and 103 above ground) [11].

Figure 5. Current metro and tramway network in the metropolitan area of Valencia. Source: Metrovalencia (2020) [12].

In this case, Valencia has a network that can be considered extensive in proportion to its territorial extension and number of inhabitants. The 72 km of line 1 have a major influence in this. It is the longest and oldest line of the network, and it corresponds to much of the layout of the extinct *trenet* (a narrow-gauge railway connecting Valencia and its metropolitan area). The density of the network, considering both metro and tram and dividing according to the number of inhabitants, equals or even slightly exceeds the statistics of Madrid and Barcelona, which gives a good impression of the existing offer for a city of the magnitude of Valencia. It should be noted that, as the construction deadlines of the future line 10 (key to the connection of the city centre with the touristic attraction of the City of Arts and Sciences and with the southern maritime façade) are gradually completed, these numbers will improve significantly. Additionally, there are plans for further expansion of the network that will be analysed in the future.

However, the frequencies of the network do not get close to the values of the major European capitals, although this does not necessarily mean that the network is badly dimensioned or operated. Each line has its frequencies, which are usually between 10 and 20 minutes, although they may be even higher depending on the destination. These will also vary depending on the time distribution (peak and valley hours) and weekly (weekdays, Saturdays, Sundays and holidays). However, many lines share an important part of their routes as figure 5 shows, especially in the city centre. Consequently, Metrovalencia manages the network so that these lines are complementary and these sections have a lower frequency in reality.

Recently, as a measure to improve the service offered, the night lines service has been extended, so that trains operate until 02:30 AM during Fridays, Saturdays and the eve of holidays, complementing the night bus lines. On weekdays, the network ends operation at about 00:30 AM and starts after 05:00 AM [13].

Regarding the spatial coverage of the network, it has been analysed considering a radius of 500 meters, which is equivalent to 8 minutes walking in normal conditions. We can observe that the coverage is wide in the capital, especially in the north-south axis that crosses the centre and the northern districts, the latter being thanks to the tramway. The south-southeast areas are currently excluded, but they will be included with the implementation of the future line 10. The following image shows in a graphic way what has been explained in this paragraph (the reader shall note that it uses the naming of the lines before the restructuring).

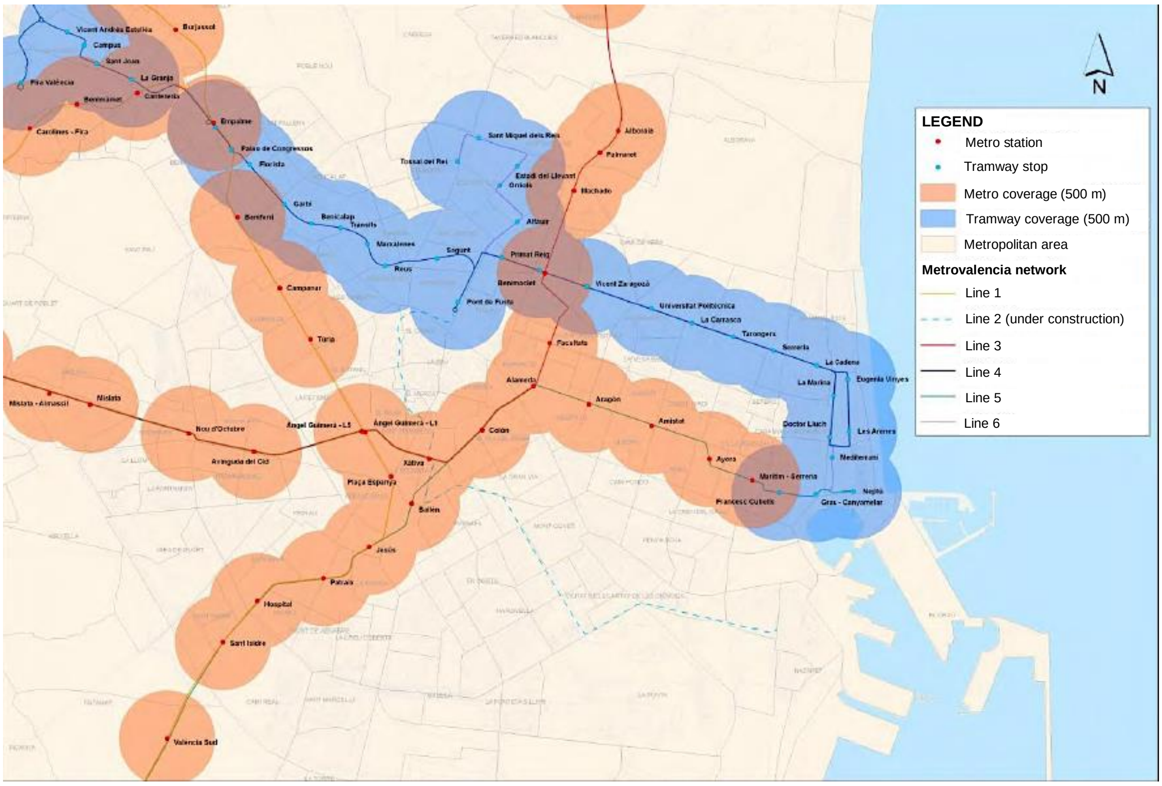

Figure 6. Territorial coverage of the Metrovalencia network in the capital. Source: SUMP of Valencia (2013) [9].

As for the metropolitan area, the spatial coverage is more diffuse due to the impossibility of ensuring the same level of service with a much more dispersed urban environment. We may observe that there is at least one station per each municipality that has access to the network. The intention appears to be that at least the urban centre and a large part of its surroundings remain within the coverage area.

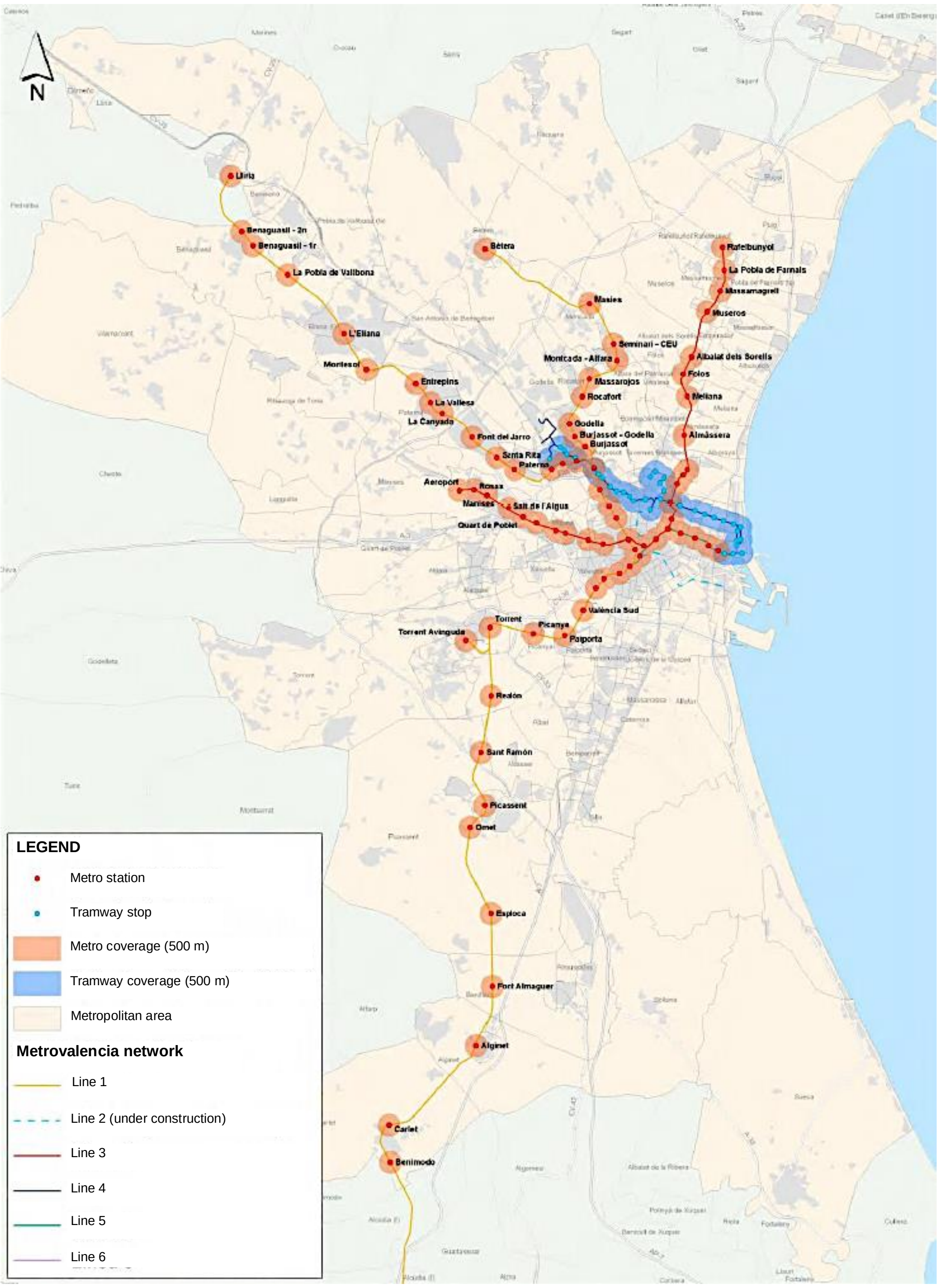

Figure 7. Territorial coverage of the Metrovalencia network in the metropolitan area. Source: SUMP of Valencia (2013) [9].

The analysis of the balance between demand and supply leads to interesting conclusions: the occupation of the trains is substantially higher than the average, both for the metro and for the tram, doubling or even tripling the data of Madrid, Barcelona or Seville. In 2017, the average occupancy was 67.3 passenger-km in the case of the metro and 42.7 passenger-km in the case of the tram, compared to 20.8 and 6.2 respectively in Madrid. This data shows us that there is a demand for this transport mode and could even justify a reorganisation of the frequencies, in case a superior budget is allocated [5].

It is also important to point out in this section the significant effort made to enhance intermodality between the private vehicle and the metro/tramway, promoting that travellers from the metropolitan area do not access the capital by car, but instead park it next to the access to the respective lines. In 12 stations, Metrovalencia provides more than 600 free parking spaces. In another 7, users can benefit from about 1,200 municipal parking spaces [11].

iv. Commuter rail

This category includes the commuter rail services provided by the state-owned company Renfe, not the medium or long distance services, nor high speed trains.

The commuter railway network (Renfe Cercanías) consists of 6 lines, numbered from C-1 to C-6, with a total of 252 km of tracks and 66 stations in 6 zones. These tracks are displayed in radial axes from the capital to the different municipalities of the province, also reaching the province of Castellón, but not the province of Alicante (Alicante, Castellón and Valencia are the three provinces that conform the Autonomous Community of Valencia).

The start of all the lines is located in Valencia, although the station may vary. Four of them begin at València Nord, the main railway station located in the city centre, and the other depart from València Sant Isidre, to the southwest [13].

Figure 8. Commuter rail network in Valencia. Source: Renfe (2020) [14].

In global terms, the offer responds to the dimensions of the metropolitan area, being the third nationally in seats per kilometre both by territorial extension and by number of inhabitants. It also keeps a logical proportion with the two main cities of the country.

In a similar way to what was previously observed in the other modes, the frequencies of the commuter rail services are very variable, although in this case these variations are more pronounced. The north-south axis lines (C-1 between Valencia and Gandia, and C-6 between Valencia and Castellón de la Plana) have more than 40 journeys per day in each direction, achieving frequencies of around half an hour. The C-2 line between Valencia and Moixent also presents these values, while the C-4 between Valencia and Xirivella increases to around an hour. This is not the case for the last two lines, whose frequency is not cyclic, but with a specific schedule instead. This is due to a lesser demand and the offer is consequently adjusted [14].

To these variable frequencies it is necessary to add what would be the main inconvenience of this transport mode in the metropolitan area of Valencia: its unpunctuality, defined as the percentage of trains that arrive at their destination with more than three minutes of delay. The data collected in 2018 by Renfe show that, during the first half of that year, the commuter rail network presented the worst values of the entire national system, being the only one not to reach 90% of punctuality and the worst evolution tendencies with respect to 2013. Furthermore, we shall add the number of cancelled trains, which amounted to 4.5% of the total in that same period, while no other commuter rail network in Spain reaches values greater than 1% [15]. An unpunctual and irregular service is not attractive to users, who will tend to favour other alternatives such as the interurban bus or, fundamentally, the private vehicle. This is reflected in the average occupancy data, with 78.6 passengers/train compared to the national average of 89 passengers/train.

As a positive fact, it can be highlighted that a large part of the stations in medium and large-sized towns are connected with other collective transport services, with correspondences with other commuter trains, urban or interurban bus lines or with the metro/tramway system in the case of Valencia. In addition, they also usually include parking facilities nearby, to facilitate the combination between the private vehicle and the railway services.

On the other hand, assuming a radius of 600 m (a 10-minute walk), the territorial coverage in this case is much more diffuse, although it follows the main urban axes of the province. Figure 9 would suggest that the northwest axis is not well connected as it has no railway lines, but it should be said that this area already has metro and interurban bus services, and the high urban pressure impedes the development of a railway infrastructure.

Figure 9. Territorial coverage of the commuter rail network in Valencia. Source: SUMP of Valencia (2013) [9].

v. Main conclusions

In short, the mobility in the metropolitan area of Valencia has some differential characteristics that make it impossible to be characterised equally in its entirety. In the capital we find preponderance of the active and of the collective transport modes, with a significant increase of bicycles and scooters in recent years. Public transport has a practically total coverage of all districts and provides an adequate level of service, with reasonable frequencies, although it could be optimised in a scenario without budgetary constraints, especially in the case of the metro and tramway network. This correct operation leads to a demand that is in line with what we can find in other similar Spanish cities.

In contrast, in the municipalities of the metropolitan area there is an increase in the use of private vehicles, which is motivated, among other factors, by a lower offer of collective public transport alternatives. In addition to the logical inability to provide an equal service in a less densely populated area, as in many other metropolitan cities, there is an interurban bus service which does not seem sufficient in terms of territorial extension and user population. Neither is the railroad an attractive alternative, considering the problems that have arisen in recent years regarding the unpunctuality and cancellation of services.

To all this we would have to add an interconnection between all networks that, although it does exist, it is hindered in practice by the amount of independent fares and the sum of travel times. For example, citizens living in the periphery of Sagunto would have to use at least three modes of transport to get to their workplace in Valencia: the city bus connection to the Sagunto railway station, a commuter train to Valencia Nord and the metro or bus to another point in the city. Adding the travel times and especially the fares, this option will probably be neglected and the citizens would choose to use their own private vehicle, faster and apparently cheaper.

It therefore seems essential to recommend an improved interurban service and a restructuring of the fare system with the aim of providing an alternative which is more attractive than the private vehicle to the inhabitants of the metropolitan area. The latter will be the basic premise that will guide this document. We will try to find a solution in the next sections, proposing alternatives for the restructuring of the network to promote its use in a sustainable way.

III. Description of the fare systems

Once we know about the mobility features of the metropolitan area of Valencia and the different public transport modes that will be analysed, we will now characterise each mode and the fares that are currently in place.

i. Zoning

The zoning of the transport network is an essential element to ensure the principle of proportionality of the system, through which the operator can allocate costs based on the distance travelled and avoid having to define a single rate that could discourage the use of the transport mode for those potential users who travel shorter distances. It is a complex process through which the territory is divided into areas, generally concentric from an origin located at a point of special relevance.

Related to the public modes of transport analysed in this study, the following aspects will be considered:

- EMT urban buses, which operate only in the city of Valencia and some close municipalities, are organised in a single area (it could be considered as zone A) [7].

- The interurban bus network includes 4 zones, as shown in figure 3. These zones are the following ones:

  - Zone A includes the following municipalities or districts located at less than 10 km from Valencia: Benifaraig, Borbotó, Forn d'Alcedo, Mislata, Poble Nou and Tavernes Blanques, in addition to the different stops within the city of Valencia.

  - Zone B covers a variable radius, about 15 km to the north and east, and up to 25 km south, with the following municipalities or urban areas: Alaquàs, Albal, Albalat dels Sorells, Alboraia (Port Saplaya), Aldaia, Alfafar, Alfara del Patriarca, Almàssera, Benetússer, Beniparrell, Benimàmet, Bonrepós i Mirambell, Burjassot, Catarroja, El Palmar, El Perellonet, El Plantío, El Saler, El Vedat, Emperador, Foios, La Pobla de Farnals and its beach, La Presa, Les Gavines, Manises and the airport, Massamagrell, Massanassa, Mas Camarena, Meliana, Moncada, Museros, Paterna, Quart de Poblet, Santa Apolonia, Silla, Torrent and Xirivella.

  - Zone C is also variable in length, reaching up to 25 km north and east, and around 30 km south. The municipalities that are included are: Alcàsser, Almussafes, Alginet, Benaguasil, Benifaió, Benissanó, Bétera, Calicanto, Carlet, El Perelló, El Puig and its beach, La Pobla de Vallbona, L'Eliana, Llíria, Mareny Blau, Masia de Traver, Picassent and the correctional centre, Puçol, Riba-roja del Túria, San Antonio de Benagéber, Sollana and Vilamarxant.

  - Zone D is the last and goes beyond the previous ones, reaching a maximum radius of 50 km. It includes the following municipalities/ urban areas: Alborache, Alfarp, Benimodo, Bugarra, Buñol, Canet d'En Berenguer, Catadau, Cheste, Chiva, Cullera, Gestalgar, Godelleta, La Vall d'Uixó, Llombai, Macastre, Náquera, Pedralba, Port de Sagunt, Sagunt, Serra, Sueca, Turís and Yátova. Some of these are exterior to what is considered as the metropolitan area.

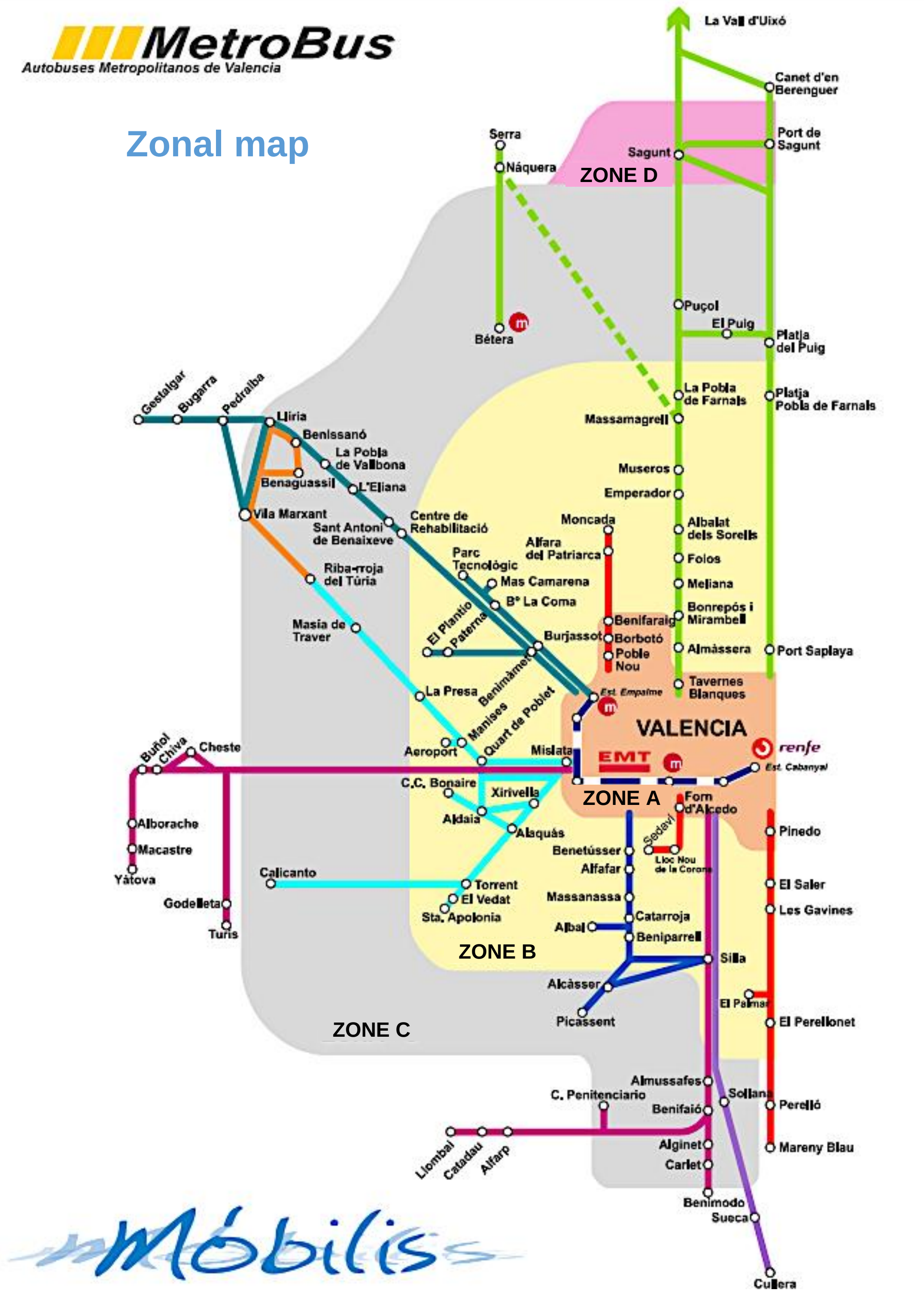

Figure 10. Scheme of lines and zones of the interurban buses network in the metropolitan area of Valencia. Source: PMoME (2018) [3].

- The metro and the tramway have also been subdivided into 4 different zones, between A and D. The zone limits have similar distances to those of the interurban buses, being of approximately 7 km to the limit of zones A and B, 15 km between zones B and C and 35 km for the start of zone D. The latter also includes the airport, despite its distance to the city, so as to apply a special fare. The following figure summarizes the zoning that has been adopted by Metrovalencia:

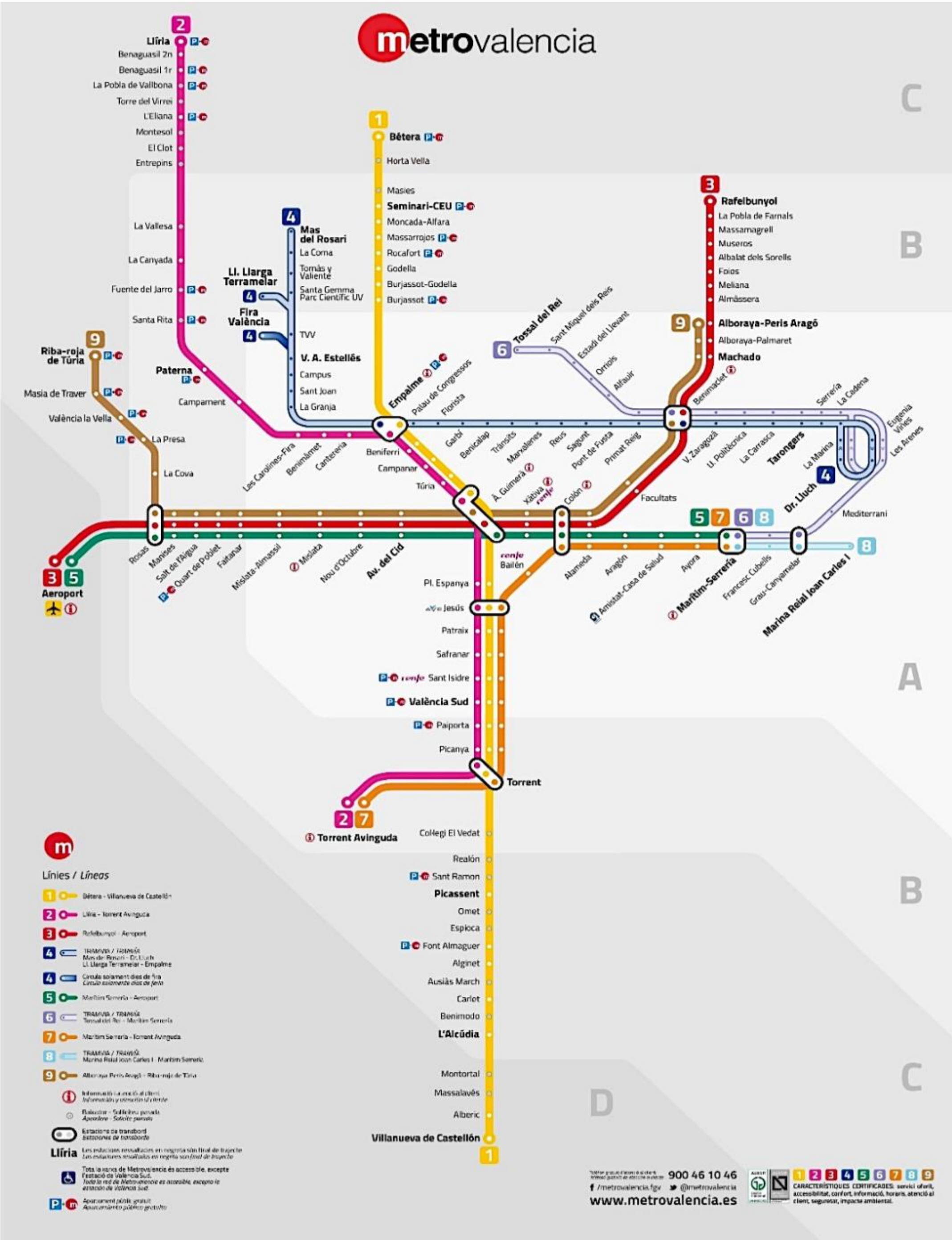

Figure 11. Zones of the metro and tramway network in the metropolitan area of Valencia. Source: Metrovalencia (2020) [12].

- In the case of the commuter rail network, given its greater extent, the zoning will include more divisions. In total there are 6 zones, with variable intervals depending on the line. They can be consulted in the following figure:

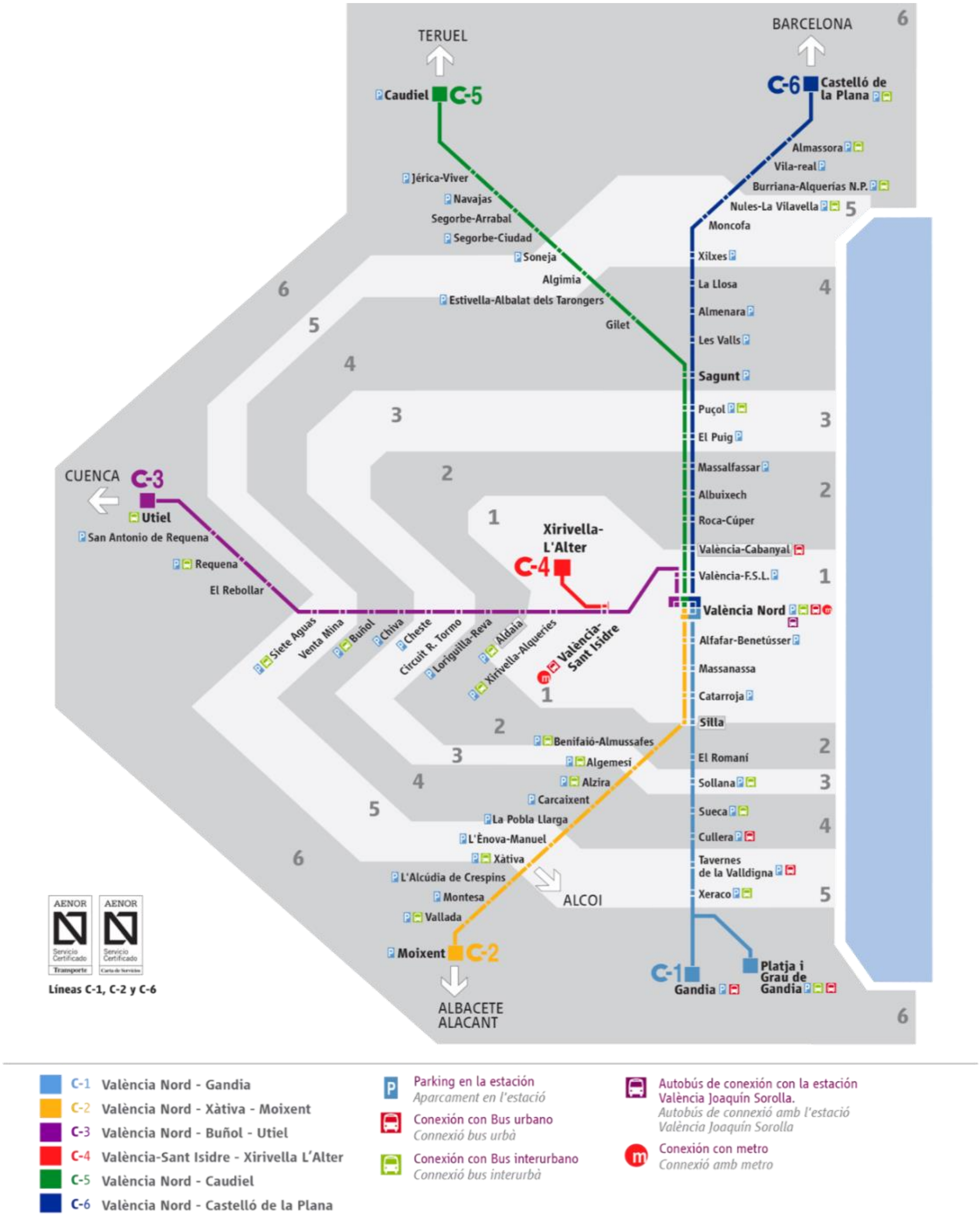

Figure 12. Zoning of the commuter rail network in the metropolitan area. Source: Renfe (2020) [14].

For the purposes of this metropolitan study, only zones 1 to 4 will be taken into account, as the other two lay outside the perimeter defined in the introduction. However, it is essential to highlight that the zoning in this network does not coincide exactly with that of the previous ones, since the first zone has a greater extension, including municipalities such as Xirivella or Catarroja (zone B for the other modes). This has been taken into account for the analysis later on.

All in all, the zoning will serve to delimit geographic areas based on the proximity to the capital, which will be managed in the same way at the fare level. The structure of this zoning responds directly to the geographical scope of each network: greater number of areas for the railway network, which reaches the entire province and part of the adjacent one; smaller for interurban buses and the metro/tramway, whose operation extends throughout the metropolitan area; and with a single zone for the urban bus, which circulates mainly through the city of Valencia.

ii. Fare system

Based on these zones, each operator has defined a series of fares that the users of the service have to pay. There are internal rates of each network, from single tickets to more complex and practical options, such as monthly tickets or reductions depending on age. In an effort to enhance multimodality, combined titles have also been created between several modes of transport, allowing the users to reduce their expenses.

a) Internal fares of each operator

A first comparative analysis of mobility in the metropolitan areas of different locations in Spain, considering all public transport modes together, shows that the price ranges for the different fares in Valencia are correct but optimisable.

The assessment is carried out by differentiating between the minimum ring, which is equivalent to the journey of an area in the capital city itself, and the maximum ring, which includes all the zones. Although this data is from a report written in 2017 [5], which has not been updated yet, this tendency prevails nowadays, as in many of these cities the fare system has remained untouched or with slight increases. The table will therefore be useful to compare, in global terms, the position of Valencia with respect to other national cities, but not for a detailed comparison in terms of percentages.

Table 1. Fares (in €) for transport tickets in several Spanish metropolitan areas. Source: Observatorio de la Movilidad Metropolitana (2017) [5].

	Minimum ring					**Maximum ring**				
	Single ticket	**Multiple ticket**	**Monthly ticket**	**Student card**	**Pension ticket**	**Single ticket**	**Multiple ticket**	**Monthly ticket**	**Student card**	**Pension ticket**
Madrid	1.50	12.20	54.60	20.00	12.30	5.10	37.40	99.30	20.00	12.30
Barcelona	2.15	9.95	52.75	105.00	-	7.60	42.05	150.00	300.00	-
Valencia	1.50	7.60	45.00	38.25	-	3.90	21.00	79.10	67.25	9.70
Seville	1.35	-	30.00	19.00	0-128	3.55	-	50.00	-	-
Biscay	1.25	-	46.00	30.00	-	3.30	-	96.00	81.00	-
Malaga	1.30	8.30	39.95	27.00	-	3.40	-	-	-	-
Zaragoza	1.35	-	42.95	-	Free	3.80	-	-	-	-
Alicante	1.45	7.60	40.00	15.00	Free	1.45	8.70	-	-	-

We can conclude that the fares in Valencia are sufficiently adjusted to allow unimodal movements in both rings. The case of the multiple ticket is remarkable, as in 2017 meant a much more important saving than in the other cities. Considering the territorial and socioeconomic context of the metropolitan area of Valencia, it seems adequate to say that, for a journey in only one way, the cost of public transport would not represent an impediment.

Furthermore, this situation has remained relatively stable over time. The single ticket fare has not increased in the last 7 years and in this decade it has only increased by 25%, which would be the lowest growth rate in the country and which shows the effort made by the operator to manage the limited budget.

However, although we can see that the fare structure is coherent with the cost intervals in other cities, the fares fixed by each operator vary considerably and contain particularities that should be defined, not only taking into account the most economical options.

Starting with the urban buses, we find a great diversity of titles and fares. A passenger can choose between using a single ticket, purchased directly on the bus, or any of the tickets purchased at tobacconists, kiosks, EMT offices, etc. and which are loaded on a contactless support known as a Móbilis card. This card, in turn, may be personalised or not, depending on whether the title is personal and non-transferable and therefore requires identification of the user.

The different titles and their associated rates can be consulted in the following summary table. Those that combine urban buses with other public modes of transport have not been considered here.

Table 2. Modalities of titles and fares of the urban buses network. Source: EMT Valencia (2020) [16].

Type	Title	Description	Fare (incl. VAT)
Not person-alysed	Single ticket	1 journey without transfers to other lines, except for the night service.	1.50€
	Bonobús	10 journeys, with unlimited transfers within an hour.	8.50€ (+2€ for the Móbilis card)
Person-alysed	Bono Oro	Annual ticket for users over 65, with disabilities or pensioners.	20€/year (+3€ for the Móbilis card)
	EMT Jove	Monthly ticket for users younger than 30 years of age.	25€/month (+3€ for the card)
	EMT ambTU	Annual ticket for unemployed people and their direct relatives, with low incomes.	10€/year (+3€ for the card)
	EMT Infantil	Annual ticket for children under 11 years.	Free (+5€ for the card)
	EMT BP General	Bonobús for a member of a general large or single-parent family.	6.80€ (+3€ for the card)
	EMT BP Especial	Bonobús for a member of a special large or single-parent family.	4.25€ (+3€ for the card)
	EMT Mascota	Biennial ticket for pets under 15 kg of weight and inside a carrier.	Free (+5€ for the card)

In the case of interurban buses, the heterogeneity between fares is greater, as there are several operators and lines of different lengths. The price to pay depends directly on the distance and there is not a specific fare per zone, but each operator negotiates the fare per kilometre instead.

It stands out that the updated information is not available in all cases, which complicates the preparation of a comparative table. As a starting point, we will use a regional law issued in March, 2018 (*Orden autonómica, publicada por la Conselleria de Vivienda, Obras Públicas y Vertebración del Territorio en el Diari Oficial de la Generalitat Valenciana*) to specify the minimum fare, which is 1.45€ for a single ticket and 1.00€ for retired people [17].

In any case, having analysed the available values, we have found that fares for a single ticket range from 1.45€ for shorter journeys and 5.10€ for the line between Valencia and Yátova by Autocares Buñol [18]. Beyond this, each operator also offers its bonuses and discounts. For example, Autocares Buñol buses include a round-trip ticket at a better price than two single tickets or multiple tickets for 20, 30 and 40 journeys on some of its lines; Fernanbus offers discounts to people over 65 and large families [19], and both Edetania and AVSA also apply these discounts to university students [20] [21].

The metro and tramway network is the one with greater diversity of transport titles, which adjust to the particularities of each user [22]. All of them are loaded on Móbilis cards, including single tickets, and can be recharged for further use. Once again, there are two types of Móbilis cards: the personalised ones, which can only be used by the cardholder, will include his/her photograph and will cost 4.00€; and the anonymous ones, which may be made out of rigid PVC or cardboard, with a cost of 2.00€ and 1.00€, respectively.

Currently, two different systems coexist:

- The traditional system proposes fixed zonal fares and titles will be restricted to the selected zone. It is more limited since the user cannot combine titles from several zones in the same Móbilis card. Therefore, if 10 journeys AB (valid in zones A and B) have been loaded on the support, it will be necessary to buy a new title to travel to a station in zone C. The traditional system includes the following titles:

Table 3. Titles and fares in the traditional system of the metro and tramway network in the metropolitan area of Valencia. Source: Metrovalencia (2020) [22].

Title	Description	Fares for 1/2/3/4 zones (incl. VAT)
Single ticket	1 journey within 2 hours after its acquisition.	1.50€ / 2.10€ / 2.80€ / 3.90€
Round-trip ticket	2 journeys, the outbound trip within 2 hours after its acquisition and the return trip before 23:59 of the next day.	2.90€ / 4.00€ / 5.30€ / 7.40€
Bonometro	Valid for 10 journeys with transfers to other lines of the network.	7.60€ / 11.00€ / 14.70€ / 21.00€
Gent Major	Monthly ticket for users over 65 years.	9.70€ (4 zones)
TAT Mobilitat Mensual	Monthly ticket for users with a disability of 64% or over.	9.70€ (4 zones)
TAT Mobilitat Anual	Annual ticket for users with a disability of 64% or over.	87.30€ (4 zones)

- The new system was created to unify all cards, to avoid fraud and to avoid distortions that would appear when, for example, a user has to make constant journeys between adjacent stations that belong to areas C and D. The traditional system would require a 4-zone ticket.

Instead of loading a number of journeys, the new system is based on an e-wallet called TuiN, which uses money directly. The fares are also adjusted to the zones, although there are exceptions for cases such as the example mentioned above, which would be considered as one zone. The title requires a personalised Móbilis card (4.00€) and has to be recharged with a minimum of 10€ and a maximum of 100€.

The TuiN title requires validating at the entrance station, where the maximum fare would be virtually discounted, and at the exit station, in which part of said amount is returned to adjust the total cost of the trip to the actual displacement. All the tramway network is considered as zone A, so validation is only required at the entrance stop. In addition, the expense is limited over the calendar month. If the user exceeds a certain value, the following trips will be free. The fares of this new system are as follows:

Table 4. Fares and monthly limits of the TuiN title. Source: Metrovalencia (2020) [22].

	1 zone	2 zones	3 – 4 zones	Airport
Cost per journey	0.72€	1.04€	1.40€	2.00€
Monthly limit	41.00€	53.00€	63.00€	72.00€

Moreover, Metrovalencia proposes several discounts to apply to these transport titles [22]:

- Large families of general category have a reduction of 20% and those of special category, 50% on all titles. The same applies to single-parent families of general and special category.
- Foster care families (those who welcome minors who cannot live with their own family for any reason) can benefit from a 10% discount on the price of the TuiN card. In the case of young people under 30 years, this discount is increased up to 15%.
- Users over 65 and pensioners will pay half the cost of a single ticket.

Finally, Renfe Cercanías uses a system which is similar to the previous ones, also based on their zoning [23]. For this study, we will only consider zones 1 to 4. In this case, the Móbilis card is not used, but their own one instead. Until February 2019, magnetic tickets were used, but they have now been replaced by contactless cards, either personalised (Renfe & Tú card, with a cost of 2€) or not personalised (with a cost of 0.50€). The following titles can be loaded on these cards:

Table 5. Titles and fares for the commuter rail network in the metropolitan area of Valencia. Source: Renfe (2020) [23].

Title	Description	Fares for 1/2/3/4 zones (incl. VAT)
Single ticket*	1 journey within 2 hours after its acquisition.	1.80€ / 2.05€ / 2.65€ / 3.70€
Round-trip ticket*	2 journeys, the outbound one within 2 hours after its acquisition and the return one before finishing the regular service on the day of its acquisition.	3.60€ / 4.10€ / 5.30€ / 7.40€
Monthly limited	2 daily journeys per month (one outbound and one return).	34.15€ / 44.20€ / 61.45€ / 81.15€
Monthly unlimited	Unlimited journeys in one month.	48.95€ / 55.05€ / 73.45€ / 97.90€
Abono Estudio	Unlimited journeys in 3 months, valid during the school period and for students.	91.25€ / 113.90€ / 178.20€ / 222.70€
Bonotren*	10 outbound or return journeys interchangeably, to be used within 30 days of purchase.	12.00€ / 13.85€ / 18.55€ / 25.15€

** Only these titles can be loaded on a not personalised card.*

Renfe also proposes several reductions to these fares [23]:

- An adult may be accompanied by up to two children under 6 years free of charge, provided they do not occupy a place.
- Large families will benefit from the same discount applied in previous cases (20% for the general category and 50% for the special category).
- If a group of 10 or more people is formed to travel on the same train, with the same origin and destination, there will be a discount of 50% in children under 11 years and 30% or 40% for those over that age in function of whether they make a single trip or a round trip, respectively.
- Those over 60 years, pensioners and people with disabilities can apply for the Tarjeta Dorada, which confers a 40% reduction in the price of the single ticket or the round-trip ticket.

Globally, we may observe that all the modes of transport analysed have fares that start at about 1.50€ for a single ticket and offer significant reductions if multiple-journey tickets or monthly passes are acquired, and if the users belong to a special social or demographic category.

All of them respect the proportionality of the system (the greater the distance, the greater the cost), except for the urban bus, which has a single fare for its entire network. Particularly important is the fact that all operate with contactless cards, since this will allow to propose integrated solutions that enable the connection between networks.

b) Combined titles

In this sense, there are already several titles that allow transfers between urban buses, interurban buses, metros and tramways. The commuter rail services are currently not integrated into this scheme [24].

The titles can be loaded on the Móbilis cards in the same way as the internal titles, since the technology used by the bus, metro and tramway operators is common. The cost of the Móbilis card for the combined titles is 5€ if it is personalised or 2€ if it is not.

The existing combinations are multiple. Starting with those that include the three networks (Metrovalencia, EMT and Metrobus), these offer more complete travel options, although as expected, the fare to be paid is higher. There are both multiple-journey tickets and 30-day passes, the latter having a special discount in case the holder is under 30 years.

Those titles that combine only two modes include either multiple-journey tickets on specific interurban lines or unlimited journeys on the capital's network for 1, 2 or 3 days. This option also includes titles specifically designed for tourists.

We must also highlight that there might be more combinations regarding interurban buses, but the information available is very scarce and informal.

Table 6. Combined titles for urban and interurban buses, metro and tramway, with their associated fares. Source: Autoritat de Transport Metropolità de València (2020) [24] and Metrovalencia (2020) [22].

Combined modes	Title	Description	Fares for 1/2/3/4 zones (incl. VAT)
Urban and interurban buses, metros and tramways	Bono Transbordo	10 journeys with a transfer in 50 minutes, only in zones A and AB. Zone A does not include interurban buses.	9.00€ / 15.50 € (only zones A and AB)
	Abono Transporte (AT)	Unlimited journeys with transfers during 30 days. The one for 4 zones does not include metro zone D.	45.00€ / 58.30€ / 68.70€ / 79.10€
	Abono Transporte (AT) Jove	AT with discount for holders of the Youth Card (*Carnet Jove*).	38.25€ / 49.55€ / 58.40€ / 67.25€
Urban buses, metros and tramways	T1	Unlimited journeys in zone A for 24 hours after activation.	4.00€ (only zone A)
	T2	Unlimited journeys in zone A for 48 hours after activation.	6.70€ (only zone A)
	T3	Unlimited journeys in zone A for 72 hours after activation.	9.70€ (only zone A)
	VLC Tourist Card 24 h *	Unlimited journeys in all zones during 24 hours after activation. Includes maps and discounts to touristic places.	15.00€ (all zones)
	VLC Tourist Card 48 h *	VLC Tourist Card valid for 48 hours.	18.00€ (all zones)
	VLC Tourist Card 72 h *	VLC Tourist Card valid for 72 hours.	22.50€ (all zones)
Urban and interurban buses	Bono Mislata	10 journeys with transfers: urban buses and interurban line 150 (Valencia – Mislata).	10.30€ (no zones)
Interurban buses, metros and tramways	Bono 10	10 journeys with transfers in zone A and interurban lines 130 and 131 (Valencia – Mas Camarena, Empalme – Parque Tecnológico).	7.75€ (zone A)

** NOTE: As it is oriented to tourists, the VLC Tourist Card title has several modalities that will modify the final price. If purchased online, there is a 10% discount on the original amount. Depending on the place where the user will collect the ticket, there might be a surcharge, unless it is collected directly at tourist offices. Therefore, the price may be increased by 3.40€ in case of shipment to the user's hotel or 5.33€ to a specific address. On the other hand, children between 6 and 12 years or groups of more than 20 people have a 15% discount on the original price.*

In global terms, we can observe that the networks' integration is fundamentally thought for urban buses, metros and tramways, and interurban buses were added later on. The option that seems to be more transversal is Bono Transbordo, as it supposes a fairly reduced additional cost compared to the internal titles. For example, a user who purchased this title would be paying only 50 cents more than the standard price of an EMT Bonobús, but in return would also be able to use the Metrobus and Metrovalencia networks in zone A. Despite this, the title is not commonly used.

On the other hand, the monthly ticket does not exist as such in the internal titles and represents an option to be considered by those who make a large number of trips in the metropolitan area. Considering a 1-zone Abono Transporte (45€), it would be equivalent to 30 journeys by interurban bus considering its cheapest single fare or 53 journeys by urban bus using the Bonobús fare. Therefore, it would be a profitable option for the traveller who needs to use several modes of transport on a regular basis. In addition, when compared with the monthly limit of 41€ set by Metrovalencia for TuiN titles, the fare seems coherent.

In any case, this integration process has not ended, as the commuter rail network is still to be incorporated. A priori, this would lead to increased fares, following the relationship previously mentioned in which a larger territorial scope and more travel options mean a greater cost of the title. However, the objective of the following sections will be to define a fare structure that allows all operators to be combined without resulting in an increase in the average costs for the users.

c) Fare systems in other metropolitan areas

We will now analyse the existing situation in other metropolitan areas, so that the fare system of Valencia can be complemented with contributions from other locations.

Firstly, we will focus on the model known as flat fare. This consists in the application of a standard single fare in a part or even in the entire metropolitan area, beyond the capital city. This option enables to attract a greater number of travellers from nearby towns that did not previously use the network and also favours cross-sectional mobility among these populations, which could imply a higher cost before since they are generally outside areas (therefore, in zone 2 or greater). However, at the same time it leads to a decrease in the income received, which has to be complemented in another way. The flat fare can be seen as an incentive to the use of public transport in the metropolitan area, having no major impact in the central area because the fares normally do not change. It would therefore be similar to the Abono Transporte (AT), only including the entire public transport network.

This flat fare model is in place in the French region of Île-de-France for all modes of public transport: metro, light rail (RER), buses, tramway, regional train services and even the funiculars of the capital [25]. The titles with flat fare require a specific support known as Navigo pass. The first one is Navigo Semaine, designed to travel unlimitedly for a week, but including zones. The Navigo Semaine can be purchased for combinations of 2 zones (2 to 3, 3 to 4 or 4 to 5) and also for all areas, but with a slight price increase. The same goes for Navigo Mois, which in this case offers unlimited journeys within a month at a much reduced price than the sum of four Navigo Semaine.

The objective of the operator (Île-de-France Mobilités) is to encourage the sustained use of the network, favouring that the frequent users tend towards the most complete solution represented by Navigo Mois. However, this title may not be as attractive to a traveller who moves only between two nearby areas, which could opt for other formulas or the private vehicle. To compensate for this, the Île-de-France Mobilités strategy involves the invention of the *dézonage* concept (no zoning in French), which eliminates all zones for standard Navigo Mois passes under certain circumstances: on weekends, holidays, from July 15 to August 15 and during school holidays. These periods coincide with leisure times and, consequently, displacements in the region are boosted, resulting in a direct competitor of the private vehicle.

Apart from the Navigo titles, there is also another one known as ImagineR. It is especially designed for young students and constitutes a complete flat rate for the entire network at a reduced annual price, at about half of the price of the Navigo Mois of all areas.

In short, the Parisian operator combines a very special flat rate scheme, focused on the purchase of monthly subscriptions for frequent travellers, and with substantial bonuses to certain groups such as students.

The financing of the operation of this system is quite complex, as expected in a network of this magnitude. The total operating cost is 10,000 million euros, according to 2016 estimates by Île-de-France Mobilités [26]. The income from tickets and credits does not cover more than 28% of the total, having to be completed with contributions from public entities and also from the private sector. On the one hand, all the municipalities that are members of Île-de-France Mobilités must make mandatory annual contributions to support the system. On the other hand, companies and public or private organizations with more than 11 employees are subject to a special rate with a variable retention percentage depending on their location in the region, in a range between 1.6% and 2.95%. Likewise, it is quite common for employers to subsidise a part of the cost of payment to their workers as part of their contract, thereby de facto financing an even greater proportion.

A similar system has also been implemented in the metropolitan area of Barcelona, coming into force in early 2019 [27]. In this case, it has been decided to include the municipalities closest to the Catalan capital in the first level of the fare structure, assimilating the displacements in these areas to those that occur in the interior of Barcelona. In this way, based on an agreement of the metropolitan transport authority (*Autoritat del Transport Metropolità*) and responding to the demands of local entities, zones 1, 2A, 2B and 2C are included in the flat rate system. This affects 36 municipalities that are included in the metropolitan area public entity, but it is necessary that the journey takes place to and from these municipalities. For exterior zones or municipalities that do not belong to this entity, the conventional fare structure is maintained. With this measure it is possible to unite the metropolitan area, avoiding the distinction between the large city and its surrounding municipalities.

The transport authority itself has estimated that, as a direct consequence of the implementation of this measure, annual travel demand will be increased by 4.6 million, which represents about 10% of the current total of 50 million in the areas concerned by the measure. The increase in costs has also been estimated, in this case between 17 and 23 million euros, which will be financed by the authority and also considering the increase in the state contribution for the financing of public transport in Barcelona, an aspect that is crucial to sustain this system.

Another alternative is the dynamic variable fare. It is the system used in the Washington DC metro, for example, and requires the implementation of complex technological resources to be able to monitor the evolution of fares in real time [28]. This allows the operator, the Washington Metropolitan Area Transit Authority (WMATA), to regulate demand in a more precise way, diverting it to other modes when there is no capacity or attracting it in valley hours. The operation of this option will be better understood through the following description.

The metro fares are calculated based on the time of day and the week in which the journey is made, differentiating between peak hours and valley hours, and also based on the distance between the stations of origin and destination. This last part uses the concept of “composite mile” for the calculation, which is calculated as the average between the distance travelled in the network between the two stations and the one that would correspond if the displacement was carried out in a straight line [29]. For the determination of the final amount, the amount is rounded to the nearest $0.05, except for the rates for the elderly and disabled users, for which the rounding is to the next lowest $0.05.

Since 1988, an increase is applied during peak system hours. These comprise from opening (generally at 05:00) to 09:30 and from 15:00 to 19:00 on weekdays. In the rest of the schedules, weekends and holidays, the valley hour rates apply, assuming a 25% discount on the previous ones. The time considered is that of the entrance validation at the station of origin. The specific amounts are indicated in the following table:

Table 7. Fares applied in the Washington, D.C. metro network. Source: WMATA (2020) [28].

Fare structure	Peak hours	Valley hours
First 3 composite miles	$2.25	$2.00
Each additional composite mile between 3 and 6	$0.326	$0.244
Each additional composite mile greater than 6	$0.288	$0.216
Maximum peak fare (exclusive of surcharge)	$6.00	$3.85

As we have seen in previous cases, WMATA also offers discounts to specific social groups. In this case, there is the fare for the elderly and for disabled people, which represents a 50% discount on the values mentioned above. In addition, there are other discounts, not present in other networks, which contribute to improving quality and user experience. This is, for instance, the "grace period", which consists of a total refund of the amount paid if the user leaves at the same station he entered during the first 15 minutes. There is also a punctuality compromise, through which the operator engages to respect the scheduled travel times. If this does not happen because there is a delay of 15 minutes or more during peak hours, an automatic refund of $3.00 would be made on the user's card. This card is the basic support for the network and is called SmarTrip. It uses contactless technology and allows the holder to register it online to obtain the usage history and review the refunds.

As it can be seen, there is a diversity of fare structures beyond the pay-per-zone, which will depend fundamentally on the level of computerisation of the network and on the economic and budgetary capacity of the operator.

On the one hand, the flat rate extended to the municipalities of the metropolitan area allows to capture a captive demand that, in general, opts for the car instead of paying for a service that usually has worse frequencies than those of the capital city. Likewise, the strategic application of this flat rate to certain titles compared to others that may be similar, as in Paris under certain circumstances, helps to guide users towards the acquisition of said titles. On the other hand, the dynamic variable rate seems the most proportional option, since it adapts better to the real distance of the stations, avoiding that short distances are penalised with respect to the long ones, and also allows a more precise management of the network, rolling the demand peaks and reinforcing it in the hours in which it is lower.

Based on these options that stem from the analysis of the state of the art and the characteristics of mobility and the public transport network in the metropolitan area of Valencia, the successive sections will lay the groundwork for the proposal of a new fare structure.

IV. Analysis of the current scenario

The current scenario in the metropolitan area of Valencia will be studied thanks to the information from the displacements database included in the PMoMe [30]. The objective will be to define an average fare for each transport mode, weighing the number of journeys according to each title with the help of the disaggregated information provided by said database.

Once this average fare is obtained by mode, it will be generalised for all journeys in the public transport network, obtaining a global cost. The model that will be defined in later sections will enable to make proposals concerning the fare structure, which will therefore lead to a new global cost. This value will be compared to the one of the current situation to assess the benefits of the proposals made.

i. Description of the initial sample

The current scenario is extrapolated from a sample of 49,788 interviews from a survey conducted in 2018 in all municipalities of the metropolitan area, each corresponding to a response on a possible displacement in that territory [30].

a) Sociodemographic analysis

A sociodemographic analysis of this information will be carried out, in order to compare it with the data of the last municipal register of inhabitants available, carried out in the municipalities of the metropolitan area in 2018 [31] and manually completed with the data of the National Statistics Institute (*Instituto Nacional de Estadística*, INE [32]) in the cases of those municipalities that are included in the metropolitan area but for which the last municipal register has no information available. If the data shows similar proportions and information, it can be stated that this sample will be representative of the reality in the metropolitan area, to the same extent that the 2018 register is.

First, in relation to the gender of the respondents in both databases, a certain similarity is observed, with a slight majority of women versus men, but very close to parity. The survey is closer to the data from the city of Valencia than that of the entire metropolitan area, sharpening the difference between genders.

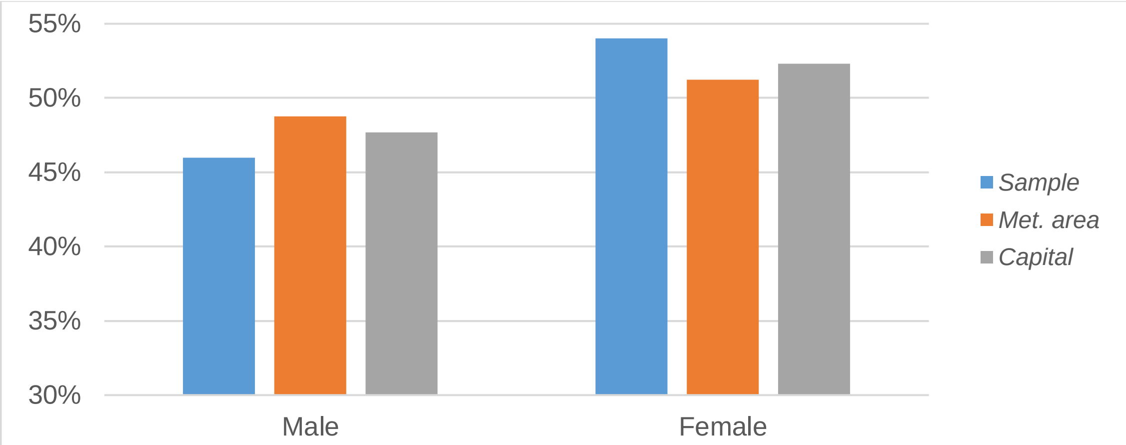

Figure 13. Percentages by gender in the sample, metropolitan area and Valencia. Sources: PMoME and INE (2018) [30] [31] [32].

The age range does show greater differences between the sample of surveyed population and the real population. The following figure shows that, with respect to the metropolitan area, the sample overrepresents the older population and underrepresents minors. If compared to Valencia, this difference is slightly attenuated, but it remains remarkable.

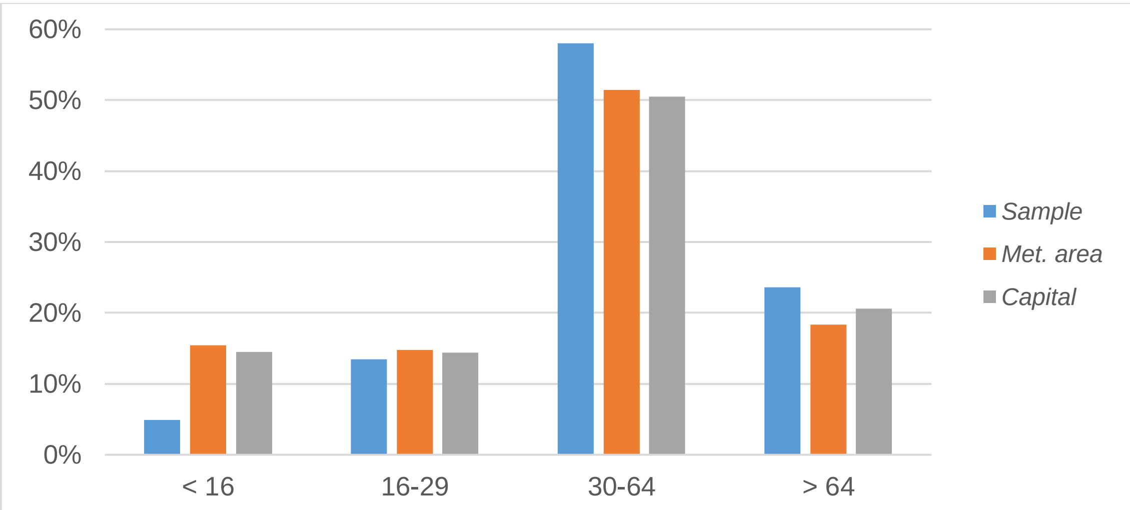

Figure 14. Percentages by age ranges in the sample, metropolitan area and Valencia. Sources: PMoME and INE (2018) [30] [31] [32].

This discrepancy could be explained by the characteristics of the survey itself, in which, for obvious reasons, very young people have not been interviewed, starting at age 5 (except for two responses of 3-year-olds). Nor are there abundant responses in the interval between 5 and 10 years. Consequently, this would lead, as a percentage, to a decrease in this range.

These apparent differences between the survey and the real population of the metropolitan area, although they are not of great magnitude, could lead to think that the sample is not representative. For this, the database of the survey has included some expansion factors for each displacement reported, which allow to extrapolate the results to the metropolitan population taking into account these divergences. While programming the model, this fact will not affect the relationships obtained.

b) Mobility trends

With a detailed analysis of the sample, interesting conclusions about the mobility patterns of citizens have been obtained.

In the first place, we can emphasise that mobility is distributed equitably throughout the week, with a certain increase on Tuesdays and a decrease on Fridays, with a non-significant oscillation that does not reach 4%. The survey has not documented journeys on Saturdays or Sundays.

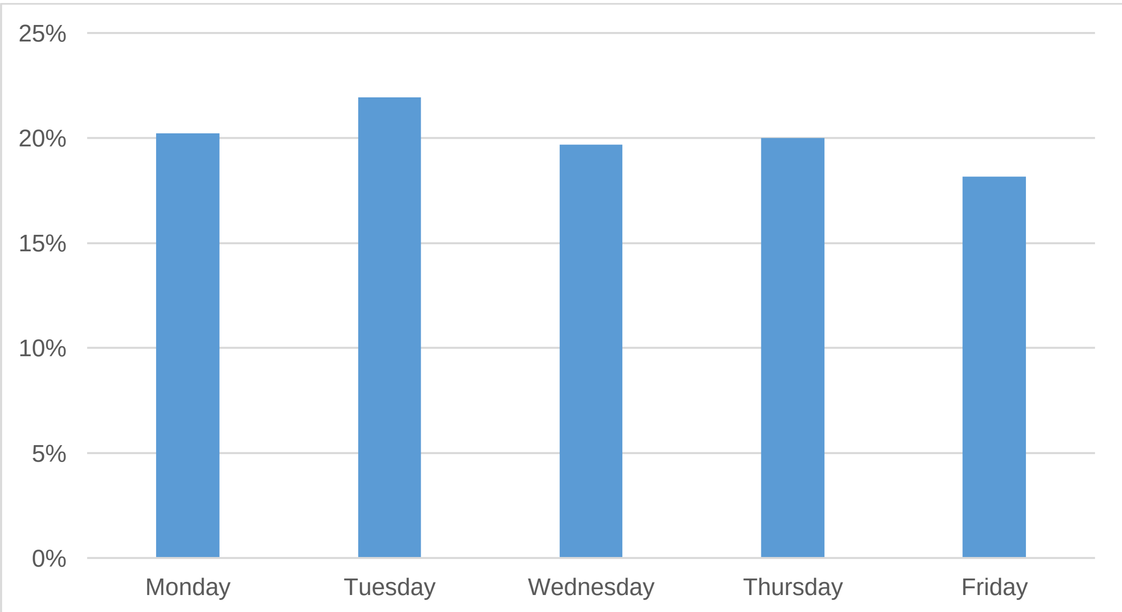

Figure 15. Percentage of journeys per day. Source: PMoMe (2018) [30].

As expected, the majority of these displacements are concentrated between the morning (from 06:00 to 12:00) and the afternoon (from 12:00 to 18:00), intervals that include the peak hours of entry and exit to the job. The night (from 00:00 to 06:00) represents around 0.5%, a circumstance that generally serves to justify the lack of public transport offer at that time.

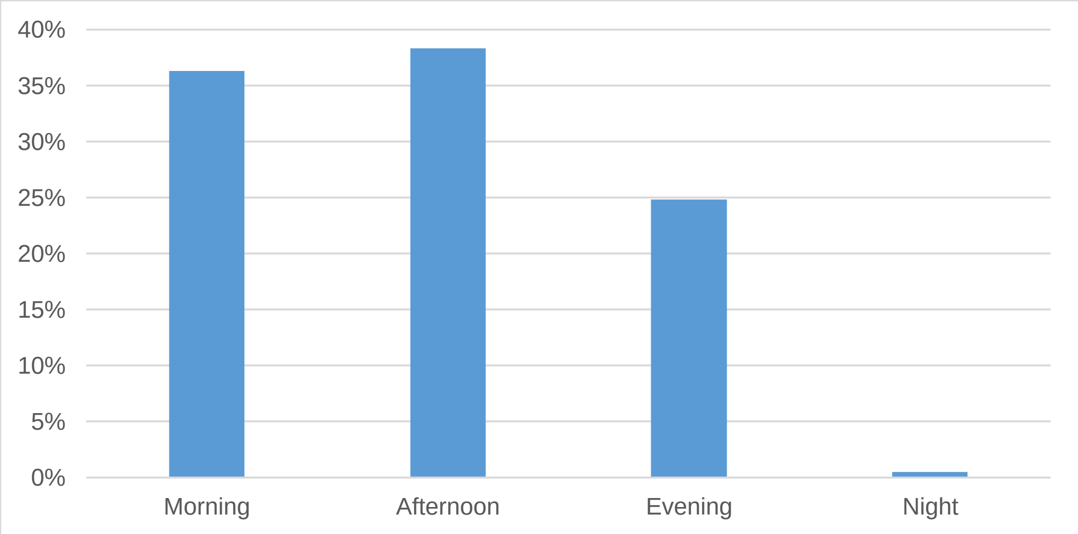

Figure 16. Percentage of journeys per hour interval. Source: PMoMe (2018) [30].

The duration of the journeys is generally short, as would be expected because the greatest number of journeys is done internally in the capital and the inner rings by urban buses and metro/tramway. It is highly infrequent to find journeys that exceed an hour, despite the extension of the metropolitan area. This could indicate a correct management of the transport routes (roads and public network), with no signs of constant congestion

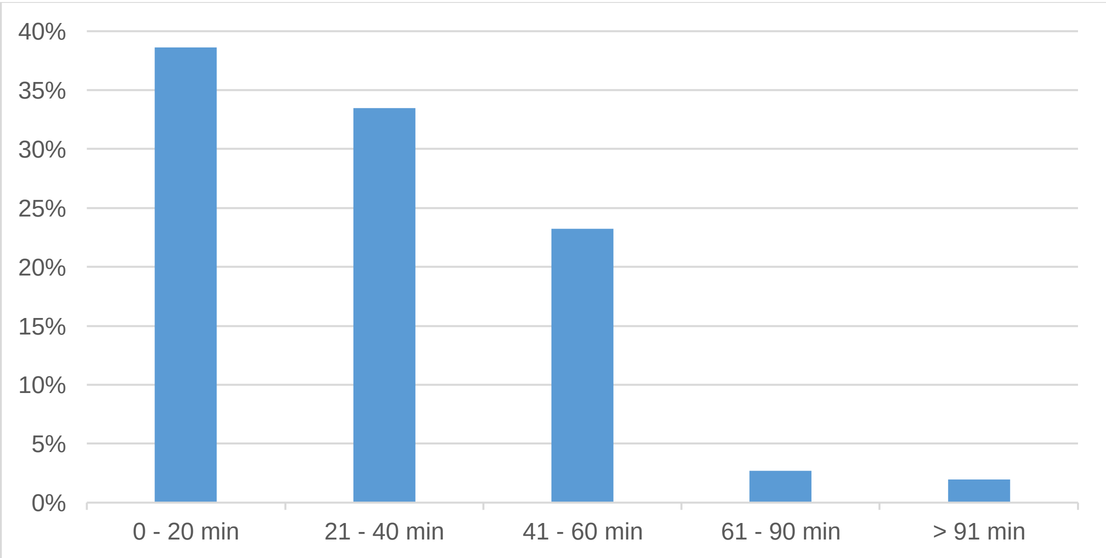

Figure 17. Percentage of journeys by duration. Source: PMoMe (2018) [30].

What mainly motivates journeys are day-to-day activities: going to work, to the university/school, to do some groceries and obviously and especially going back home. These four reasons account for 3 out of 4 trips in the network and defines certain patterns that the public network should interpret to attract more demand. These "forced" patterns of people who travel every day, or at least every working day, are followed by other reasons such as personal/work issues or accompanying someone, which can also be a demand that is susceptible of being captured by an extensive, rational public transport network.

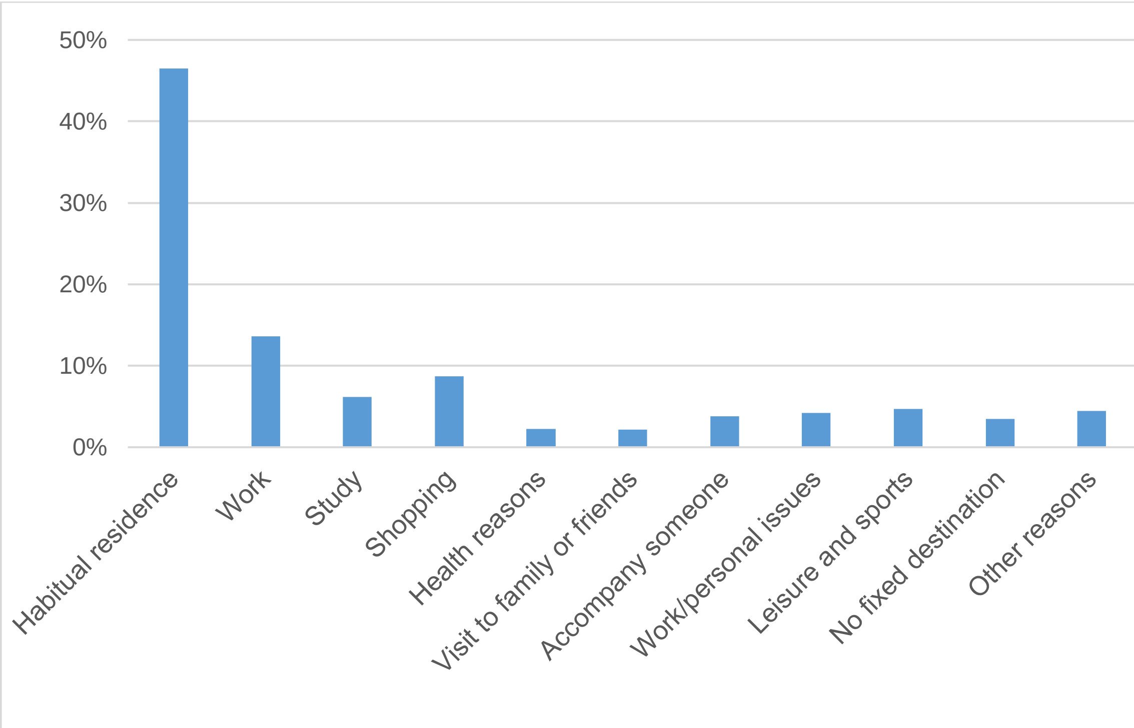

Figure 18. Percentage of journeys by motive of the displacement. Source: PMoMe (2018) [30].

All in all, the sample does not show any evident sign of lack of representativeness. The figures display the typical mobility trends that can be found in similar national cities. We conclude that this sample is valid for our calculations and procedures.

ii. Limitations of the sample

The sample can be used in terms of modelling, but it has to be adapted to ensure that the results are valid. Some entries will be discarded because they are not coherent in this context, others are errors that have not been conveniently filtered before the database was published.

a) Internal limitations of the sample

Of the total number of respondents in the survey, 2,835 data entries (5.69%) correspond to people who have answered to the survey but have reported no displacement on that specific day. Although they are necessary to extrapolate the results to the total population with the expansion factor and for the characterisation of mobility data, for the purpose of defining the explanatory model these responses will not be counted, the study being limited to those displacements that have taken place.

Some answers refer to a municipality that is outside the metropolitan area (represented with the code FUERA AM), so they will also be eliminated as they are not included in the scope of this document. This corresponds to 753 data entries in total, 1.51% of the initial sample.

The final sample is therefore reduced to 46,200 data entries. However, in order for the model to provide representative results and to be able to be calibrated with the real situation, we must include the necessary corrections, in addition to the limitations that the sample already presented and that have been explained above.

b) Limitations induced by the model

The future model will allow to explain the modal share according to the main variable that drives behaviour: user costs. We will use a statistical model that needs specific information and, at the same time, does not admit some aspects.

To begin with, 29 records (0.06%) do not include enough basic information to be processed by the model, so they will not be considered. These are those entries that do not inform about the journey times, which is necessary to estimate the travel costs. If a monetary cost cannot be deducted, the model will not be able to take these answers into account.

The model will explain the use of private vehicles or public transport (modal share) according to some explanatory variables. Therefore, we will require responses that correspond to these type of users and will have to exclude pedestrians, cyclists and similar. We will also eliminate those who use both private and public modes during the displacement that they relate, as it is not possible to determine which part of the journey has been made with which mode. This affects to 21,439 data entries in total (43.06%). Out of these eliminated answers, more than 90% are pedestrians.

In addition to this, the model assumes that the user can choose between both options freely, with no restrictions. For this to be real, we cannot have answers of people who do not have access to a private vehicle, because they will have to use public transport instead. As a consequence, their choice will not be driven by any of the variables that our model may operate with, but by the context itself. In order to implement this, we have accessed the demographic database of the PMoMe [30], which mentions if each respondent has access to a private vehicle. By introducing this filter, we have 2,111 additional disregarded data entries (4.24%).

Finally, following the objective of this document, we will only analyse the connections of the capital and the other municipalities of the metropolitan area, which represent a considerable percentage of the daily displacements, especially with people that go to work or study to Valencia from other places. We have chosen not take into account transversal journeys, which are negligible if compared to the axial displacements, nor those which take place within the same municipality. Furthermore, we will add a last condition: the origin of the displacement will be in a municipality from the metropolitan area and the destination will be Valencia. By doing this, we do not consider twice those cases in which the respondent declares the same journey (one outbound, one return), which would lead the model to stablish correlations with the same people and to distort the possible results. However, this will be then taken into account when expanding the results of the model to the reality. This is the case for 19,090 data entries (38.34%)

The final sample is reduced to 3,534 data entries, enough to realise the needed calculations. This means that 7.1% of the initial sample is used in the model, which will then be extrapolated to the entire population thanks to the expansion factors.

iii. Average fares

When comparing the modes, it is convenient to calculate average fares, so that we may obtain information on the average cost for the user who uses each of them and so that we can see the different mobility trends in the network. If one mode is singularly more expensive than the others, we may propose specific solutions. In addition, the ultimate goal of this study is to achieve better interconnection between modes and a lower overall average fare.

To calculate these values, we have filtered the PMoMe database so that it shows the frequency of use of each specific type of title within each public transport mode. At the same time, these types have been multiplied by their corresponding fare, as defined in section III.ii. Fare system. The results are then divided by the total number of uses. Thus, a representative weighted average fare of each transport mode can be calculated.

To take into account correctly the amounts associated with each title, the following hypotheses have been considered:

- The fare corresponds to the price of a journey according to the title considered. In the case of temporary passes, which allow unlimited journeys over a period of time, it will be assumed that 2 journeys are made per working day (for a total of 40 journeys per month). Possible transfers are also counted in this value.

- In the event that the respondent has answered that he or she has used a different title to those listed, does not know or does not want to answer, a cost equal to the average fare calculated without considering these answers will be applied to his/her journey.

- Those titles that allow transfers will only be taken into account once if they are used in the same mode. As an example, if an EMT Bonobús is used for two consecutive journeys on urban buses within one hour, the second one will be counted as free, as it happens in reality. Therefore, it will not sum in terms of cost, but it will do on the total of journeys.

- In the combined titles, the cost will be divided in equal parts between all the modes used. For example, if a Bonotransbordo zone A ticket is used to travel by metro and bus, the fare will be split in half between the metro and the urban bus.

- Some inconsistencies in the responses have been detected, with validations of titles in modes to which they do not correspond. We have manually identified these errors and chosen to assimilate the title to the most similar one that the operator really offers. Specifically, the corrections made are the following ones:

    - The 10-journey titles will be assigned to their correct mode. For example, in the case of the urban bus network, a 10-journey Bonometro response will be considered as a 10-journey Bonobús.

    - Regarding the possible confusions with names, Abono Transporte Mensual will be a valid title for the metro and tramway network, and Abono Mensual Limitado for the commuter rail network.

  - For interurban buses, average data from the different operators will be used, both for single tickets and for monthly titles. Bonobús responses will be assimilated to passes of 10 journeys.

  - The emission cost of the card has been deliberately left out. In the scenarios to be tested, the cost of the unified physical support would have to be added to the final results, but we only consider fares in our calculations.

- In those titles which are not directly linked to a specific zone, it has been decided to individually analyse each journey and infer the corresponding zone from the origin and destination, taking the option of the most restrictive title. For example, if the journey is from Valencia (zone A) to Bétera (zone C) and the user has used a Bonometro, it will be assumed that it is of type ABC. However, there is no way to discriminate between journeys to the Manises station or the Airport, both labelled as Manises, so these will all be assumed as zone D.

- Another hypothesis is that the Tarjeta Dorada discount of the commuter trains will be applied to the normal price of a single ticket of the corresponding number of zones.

After having filtered the database and made all the calculations, the following average rates have been obtained, according to each transport mode:

Table 8. Average fare for each public transport mode.

Transport mode (operator)	Average fare
Urban buses (EMT)	0.89 €
Metro and tramway (Metrovalencia)	1.08 €
Interurban buses (Metrobus)	1.79 €
Commuter trains (Renfe)	1.52 €

The intermediate results including the number of tickets per mode and the associated costs are included in annex 3.

A first glance allows to confirm that the average fare increases as the geographic extension of the network grows, as a direct consequence of the zoning. We can also comment on the importance of monthly passes and multiple-journey tickets, which cause the average fare to differ markedly from the price of a single ticket. This is singularly important in the case of the urban buses and of the metro and tramway, used in daily home-work journeys and for which these types of titles are usually chosen. On the contrary, in the case of interurban buses and the commuter railway there is a greater proportion of simple tickets, which could be explained by occasional journeys to/from municipalities in the metropolitan area for reasons other than going to the workplace (routine). In any case, the average fare is still significantly lower than the single ticket in one zone. Certain social groups contribute to this situation, with the very low fares of the Tarjeta Dorada or the Abono Transporte Jove Mensual.

The results obtained are sufficiently representative of the real situation, with a large sample that includes a minimum of 70 journeys per mode. The amount of data is much higher in the case of the metro and tramway, with over 600 data entries. The application of the expansion factor ensures that the extrapolation of the conclusions to the public transport network as a whole is feasible and that it provides sufficient reliability.

Finally, we will weigh each average fare by the number of journeys per mode, so that a global value is obtained:

$$\text{Global average fare} = \frac{\sum(\text{Average fare}\cdot\text{nb.journeys per mode})}{\text{Total of journeys}} = \tag{1}$$

$$\frac{0.89 \cdot 150 + 1.08 \cdot 633 + 1.79 \cdot 116 + 1.52 \cdot 70}{148 + 633 + 116 + 70} = \mathbf{1.16}\ €$$

The result obtained is an average user cost of one euro and sixteen cents in the network.

iv. Analysis per corridors

The study of the previous section shows the methodology applied, as well as the trends and results obtained globally, considering the network in its entirety. In this section, a more detailed analysis of the routes between Valencia and its metropolitan area will be carried out by corridors that will allow a better understanding of the behaviour patterns, following the division and methodology of the PMoMe.

However, some of the corridors defined in the PMoMe will be merged according to their geographical direction, as it would not be logical to maintain independent corridors which are contiguous and in the same direction (for example, the Horta Sud corridor and the Southern corridor). Four large groups are created according to the main urban development directions of the metropolitan area:

- Northern corridor: It integrates commuter rail lines C-5 and C-6, as well as the interurban bus lines providing service to municipalities close to roads CV-300 and V-21 until Sagunto and Vall d'Uixó.

Figure 19. Northern corridor. Source: Metrovalencia, Metrobús, Renfe (2020).

- North-western corridor: It concerns the interurban lines between Valencia and the municipalities near the road CV-35, branching off at its end and reaching Moncada, Llíria, Serra and Porta Coeli. There are no commuter rail lines in this corridor.

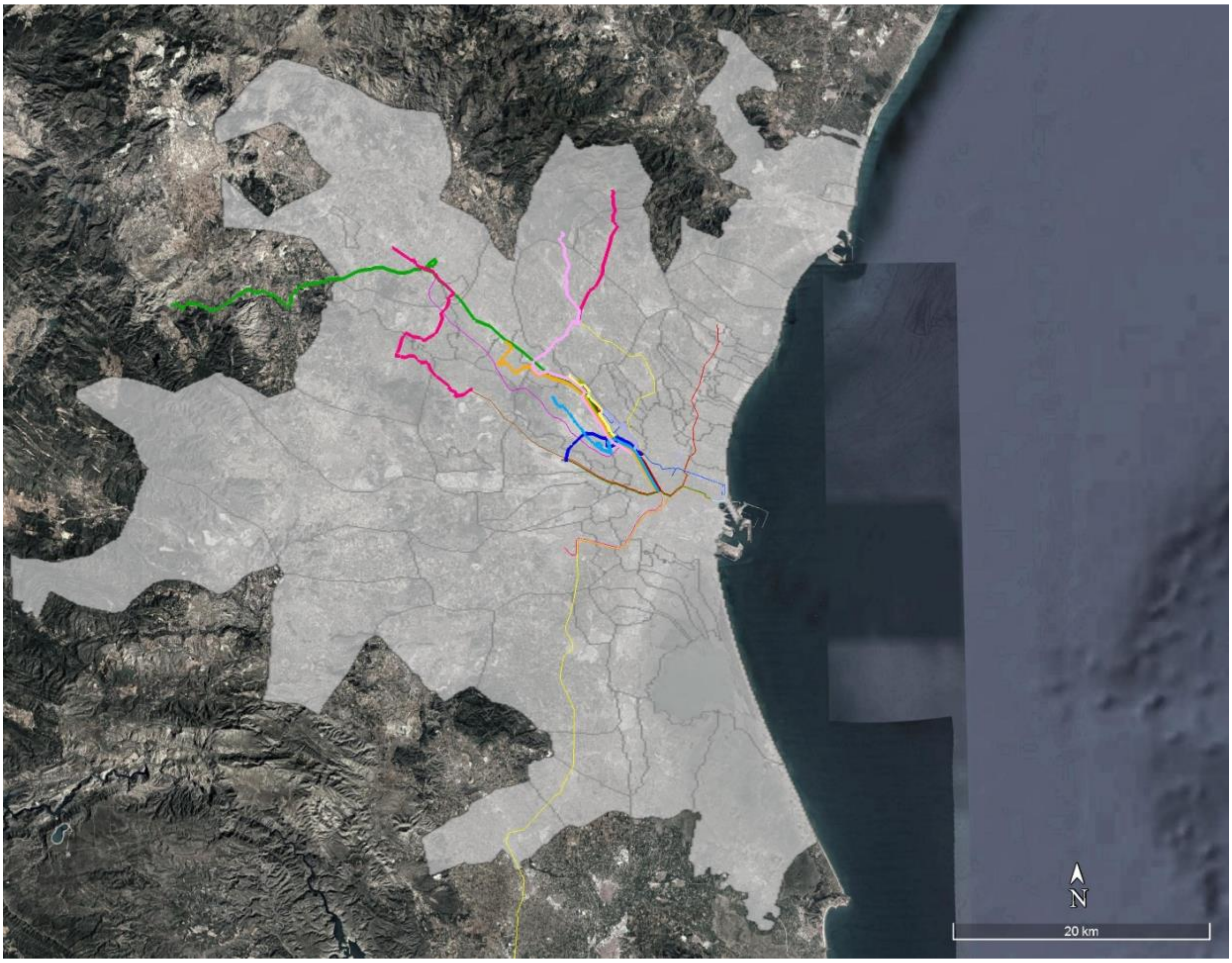

Figure 20. North-western corridor. Source: Metrovalencia, Metrobús (2020).

- Western corridor: It includes commuter rail lines C-3 and C-4, as well as the interurban bus lines between Valencia and Alaquàs, Aldaia, Calicanto, Chiva, Manises, Mislata, Quart de Poblet, Vilamarxant and Xirivella.

Figure 21. Western corridor. Source: Metrovalencia, Metrobús, Renfe (2020).

- Southern corridor: It includes commuter rail lines C-1 and C-2, as well as the interurban bus lines that give service to the municipalities of Albal, Alcàsser, Alfafar, Benetússer, Beniparrell, Catarroja, Massanassa, Picassent, Sedaví, Silla, Sueca and Torrent.

Figure 22. Southern corridor. Source: Metrovalencia, Metrobús, Renfe (2020).

The previous figures show the layout of the network by corridors, eliminating the EMT urban bus routes to avoid overloading the image. The thinnest lines correspond to the 9 metro and tramway lines, the intermediate ones with train logos are the commuter railway lines and the thickest ones show the interurban bus lines. The shaded surface defines the metropolitan area of Valencia.

The process carried out above will be repeated, classifying every displacement according to their corridors. To do this, we will look at their municipality of origin. The results obtained vary slightly when compared to those of the general network, showing an increase in modes that normally imply longer distances, such as commuter trains or interurban buses. The following graphs will help to visually understand the existing distribution, both in the entire network and by corridors:

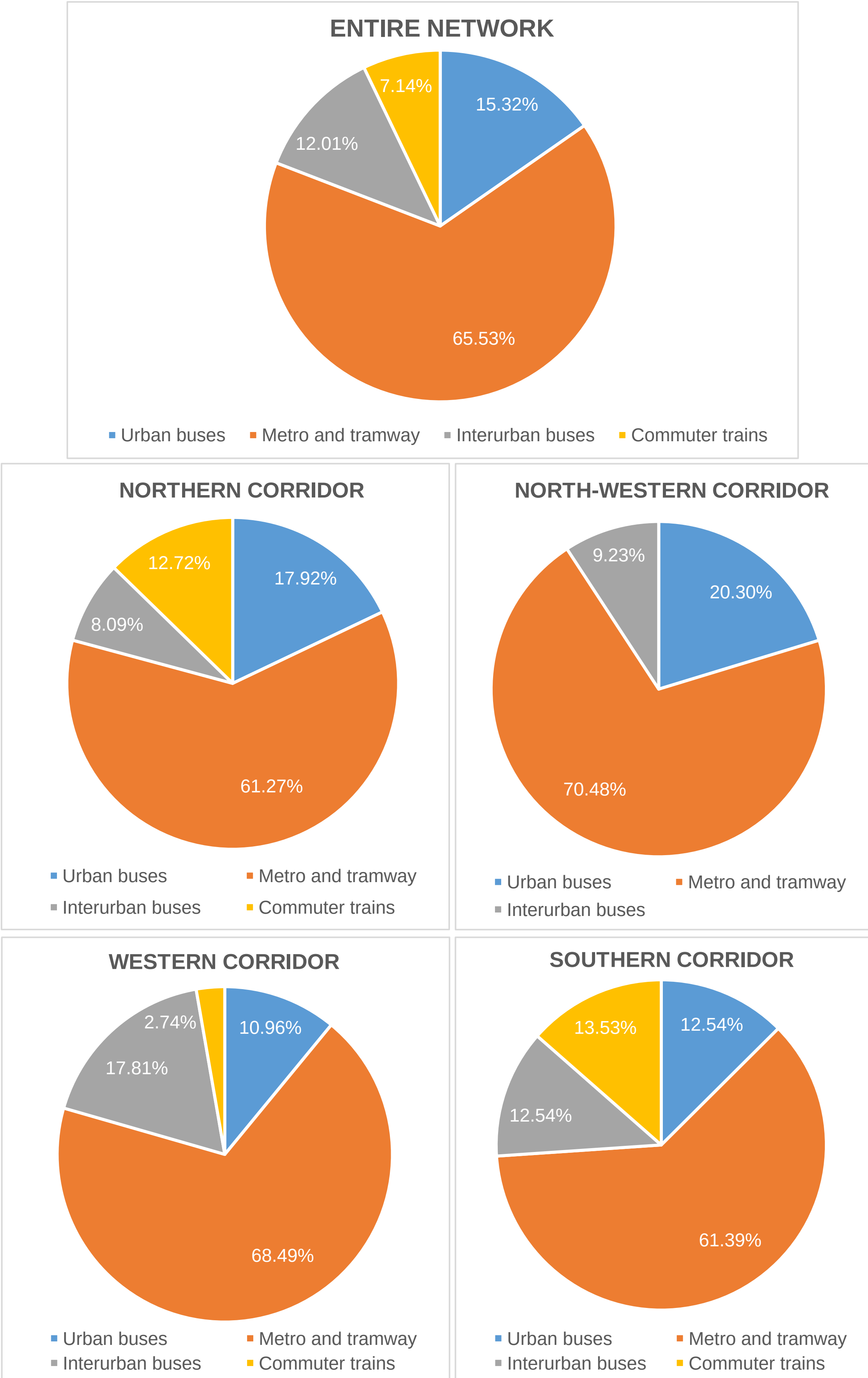

Figure 23. Percentage of use of public transport modes in the entire network and by corridors.

By focusing specifically on mobility by corridors, whose improvement is the main objective of this document, the sample is smaller in each case, but it will still allow to draw several conclusions.

The first is that the commuter railway gains weight in the north-south axis, with lines C-1, C-2, C-5 and C-6 as the main exponents, efficiently and quickly connecting populations that are located at a certain distance from the capital and for which the interurban bus would not be an advantage in terms of speed and travel time. In municipalities such as Massanassa, Almussafes, Silla, Catarroja and Benifaió, of a certain entity and attractors of displacements due to their nature of employment poles, good rail connections with the capital lead to a greater use of this mode. The same happens in the connections of the capital with the northern municipalities, such as Puçol, El Puig or Sagunt.

This effect is enhanced in the metro and tramway network, a more flexible alternative than the previous one because of its greater number of stations and consequently greater coverage density. Its percentage becomes the majority in all corridors, this being explained by the large number of journeys between the municipalities connected by the metro lines and the capital. The furthest municipalities, with no rail alternative of any kind, have a greater number of journeys made by private vehicle. The northern and southern corridors seem to slightly contradict this trend, with a lower percentage than the others, but this is due to a better service and connections by train.

Despite the remarks made in previous sections, interurban buses reach a significant percentage in these cases, especially in the western and southern corridors. These coincide with important industrial and leisure areas, which are not sufficiently connected through the previous modes. The interurban bus, as it is not as rigid, can travel along a route which adapts better to the demand of these passengers and brings them closer to their final destination. Consequently, it will capture part of the demand of the commuter trains, in the case of the southern corridor, and of the metro, in the case of the western corridor. For this last one, the Cercanías network is only used for the furthest connections, starting from Aldaia and ending in Cheste and Loriguilla, but its use is rather testimonial.

This shows the importance of integrating the commuter railway in the new system with a focus on the northern and southern corridors, and of enhancing the use of the interurban bus in mainly home-work or leisure trips as an alternative to the private vehicle where no rail modes are available.

With respect to average fares, the cost by corridors will increase. The greater weight of the modes with higher fares and further zones, motivated by the greater distance of travel, entails a need for higher spending for metropolitan users, who do not always tend towards integrated solutions that lower costs. This fact seems to affect to a greater extent the users of the south and the west, who have provided answers with a higher associated cost.

Table 9. Average fares (in €) by corridor, analysed by mode and globally.

Average fare	Corridors				
	Entire network	**Northern**	**North-western**	**Western**	**Southern**
Urban buses	0.90	0.96	0.82	0.99	0.96
Metro and tramway	1.07	1.00	0.99	1.22	1.09
Interurban buses	1.79	2.77	2.44	1.52	1.48
Commuter trains	1.52	1.96	-	1.58	1.38
Global	**1.16**	**1.26**	**1.09**	**1.26**	**1.16**

The corridors show the same pattern that we have been able to observe before: the transport modes that reach longer distances logically imply a higher cost. The abnormally high values obtained for interurban buses in the northern and north-western corridors are due to a very small sample, with less than 25 responses. In both cases, the majority of respondents stated using single tickets for 4 zones or said that they did not recall the specific title. This has caused a distortion in the average fares.

The impact of the commuter trains is also remarkable: the only corridor which does not have any line has a global average fare that is significantly lower to that of the other corridors. Currently, a user of commuter trains has to purchase different titles as there is no integrated solution, so this implies a higher cost.

In short, the proposed new structure must find a solution to this context, incorporating the commuter rail network into a combined solution and encouraging the acquisition of multiple-journey tickets or temporary passes, which substantially reduce the cost per journey for the user. This will lead to lower global fares, avoiding divergences that tend to exclude passengers of specific zones from the daily use of the system.

v. Influence of other motorised transport modes

To conclude the definition of the descriptive model, we must incorporated the other motorised modes included in the database. In this case, as part of the private vehicles category we will consider the car and the motorcycle, and both as drivers or passengers.

Since the model will mainly use the cost as an explanatory variable, a value of that variable must be inferred for each of the displacements described. The problem with this approach is that the only references are the municipality of origin and destination, without any indication of the specific addresses, and the duration of the displacement, subjectively estimated by the user in minutes. In order to deduct the cost values, this last variable will be used, although it is an estimate that may introduce some error in the results. This methodology will be accepted in the context of this study, in the absence of more precise information.

Once the duration, origin and destination of the journey are known, it will be possible to determine the distance travelled, applying an average speed to each time. This speed will be logically variable depending on the journey, but it will be simplified by adopting a common value for all metropolitan journeys. With the help of the Google Maps cartographic system, a broad set of database paths has been simulated, at different time slots of the day, then estimating an average speed that is approximately 60 km/h. This is the value that will be adopted as a reference for displacements between municipalities in the metropolitan area.

Next, the vehicle pool will be characterised, distinguishing with regard to the source that powers the vehicle. For this, the data disaggregated by province of the national transit entity (*Dirección General de Tráfico,* DGT [33]) will be used. The DGT establishes that in 2018 in the province of Valencia there were a total of 944,558 diesel vehicles and 764,463 gasoline vehicles, which corresponds to a diesel/gasoline distribution of 55%-45%. Taking as reference the report made public in 2017 by the PSA group [34], which includes car brands such as Peugeot or Citroën, an average consumption of 6 l/100 km will be considered for gasoline vehicles and 5 l/100 km for diesel vehicles. Motorcycles are only gasoline-powered, so no distribution needs to be determined.

To translate this information into costs, the sale price of each fuel must be applied. The Ministry for the Ecological Transition and the Demographic Challenge provides data updated daily for all Spanish service stations. After filtering to have the results of those that correspond to the municipalities of the metropolitan area, an average of 1.28€/l is calculated for type 95 gasoline and 1.18€/l for type A diesel (updated on February 17th, 2020 [35]).

The next formula will be applied to calculate costs:

$$\begin{aligned}\text{Cost (€)} &= \text{Duration (h)} \cdot \text{Average speed} \left(\frac{\text{km}}{\text{h}}\right) \\ &\cdot \sum \text{Average consumption} \left(\frac{\text{l}}{\text{km}}\right) \cdot \text{price} \left(\frac{\text{€}}{\text{l}}\right) \cdot \text{\% vehicle pool} \qquad (2) \\ &= \text{Duration} \cdot 60 \cdot (\frac{6}{100} \cdot 1{,}28 \cdot 0{,}45 + \frac{5}{100} \cdot 1{,}18 \cdot 0{,}55) \\ &= 4{,}0206 \cdot \text{Duration}\end{aligned}$$

V. Modelling

In this section, we will define the model used to describe the behaviour of the metropolitan transport users. We will use a discrete choice model [36], which will describe the demand of each transport mode according to the cost for the users.

i. Theoretical basis

In a discrete choice model, it is essential to start from the concept of generalised cost, defined as the direct cost derived from the use of a transport mode and the economic value of the variables that have an influence on the users' decisions. In the context of this study, it has been decided that only the cost of the ticket for public transport modes and the fuel for private vehicles will be taken into account, without reference to external elements such as added taxes or maintenance, given that the users usually consider essentially these first costs when making their decision about the mode of transport.

We will follow the theory of random utility, which allows to address empirically the modelling of demand according to possible choices between a set of discrete alternatives (in this case, each mode of transport). This theory states that the population is homogeneous and that individuals behave in a rational manner, being aware of all the information when making their decisions. The option they will choose will be the one that maximises utility, taking into consideration the possible restrictions and their socio-economic characteristics. Knowing exactly what utility each individual associates with each alternatives involves great difficulty, so the associated probabilities are treated as random variables. According to McFadden [37], the function that defines this utility can be expressed as the sum of an observable or representative component and another unobservable component that is random in nature.

The model will be based on determining this utility function, which enables to represent -as faithfully as possible- what is happening in reality. This begins with the delimitation of the set of choices. In this case, it will correspond to private vehicles and any of the four public transport modes described above. The restrictions that affect in our case will be physical, since the existence of stops of the public transport network in the municipality will directly condition the user's choice: if there are not any stops nearby, the user will probably opt for any of the private vehicle alternatives instead of going to the nearest public transport stop in another municipality.

We will use a logit model [38], which presents a utility function defined as follows:

$$U_i = V_i + e_i \tag{3}$$

This follows McFadden's indications as it includes the term V(i), which represents the deterministic function of the attributes of option I, and the term e(i), which corresponds to the random component of the utility function. In this case, i will have two possible values: public transport modes, on the one hand, and private transport, on the other.

The deterministic term can be broken down into a sum:

$$V_i = b_0 + b_1 x_1 + \cdots + b_k x_k \tag{4}$$

Where:

- b_0 is a constant that represents the influence of unobservable characteristics.
- Terms b_k are coefficients that weigh the variables and vary according to the mode.
- Terms x_k are the variables of the model, which change according to the k attributes considered.

Then, a user will choose an option i over any other option j provided the utility of i is greater, that is:

$$U_i \geq U_j \;\; \rightarrow \;\; V_i + e_i \geq V_j + e_j \;\; \rightarrow \;\; V_i - V_j \geq e_j - e_i \qquad j \neq i \tag{5}$$

The probability that option i will be chosen will correspond to:

$$\begin{aligned} P_i = P\left(U_i \geq U_j\right) = P\left(U_j < U_i\right) = P\left(e_j - e_i < V_i - V_j\right) = \\ = P\left(e_j < V_i - V_j + e_i\right) \qquad j \neq i \end{aligned} \tag{6}$$

It will be necessary to make some hypotheses to develop these expressions. First, it must be assumed that the terms e_i are independent and identically distributed. Second, the type of probability distribution function selected for the difference $e_j - e_i$ will lead to different models. Considering a Gumbel or extreme value distribution, the logit model expressions will be obtained.

Returning to equation (6), the difference between the terms V responds to a cumulative distribution of the difference between the terms e, so the probability P_i, knowing that it is a logit model, will follow the expression of a logistic density function:

$$P_i = \frac{e^{V_i}}{e^{V_i} + e^{V_j}} = \frac{1}{1 + e^{-(V_i - V_j)}} \tag{7}$$

In the case of a binomial logit model, that is, one that depends on two variables such as cost and time, a calibration parameter will appear in the model, represented by the Greek letter β, and will multiply the difference of V in the exponent of the denominator. This parameter has a value that, as Juan José Pompilio explains [39], can range between 0 and 1. When approaching 1, the error considered in the declared information will be minimal. In this case, a value of 1 will be used, leaving then the formula as stated in (7).

This will therefore be the model considered, which will allow us to accurately represent reality, although with certain limitations:

- As the calibration parameter is assumed constant, possible random variations will not be considered in the tastes and preferences of the users. This implies that, if the explanatory variables of the model are modified, they will all present an identical response.
- The alternatives will be completely independent.
- Possible correlations between the observed data are not taken into account.
- Differences in the variability of the utility for different users or alternatives are not considered either.

ii. Preparation of the model

The input data of the model will come from the displacement database of the PMoMe, after the filtering process due to the aforementioned limitations. The variables that will be considered at the beginning will be the ones listed below, either directly with the coding of the database or with a new code that has been defined manually:

- Travel day: In order, from Monday (1) to Friday (5). Theoretically, it should also include Saturday and Sunday, but the survey did not include these days. For the model, the intermediate days of the week will be grouped, as their mobility conditions are very similar, compared to those on Monday and Friday.

- Gender: Men will be assigned number 1 and women, number 2.

- Age: Each person interviewed indicates their age in years. This will then be grouped in five different age ranges defined by the database, which vary as follows:
    - 1: From 5 to 17 years.
    - 2: From 18 to 44 years.
    - 3: From 45 to 64 years.
    - 4: 65 to 79 years.
    - 5: More than 79 years.

- Transport zone (origin and destination): The code follows the division by transport zones of the PMoMe, normally at a lower level than the municipality. It identifies the areas of origin and destination of all displacements.

- Professional activity: Employment of the person surveyed, classified as follows:
    - 1: Students.
    - 2: Unpaid domestic work.
    - 3: Unemployed person, who is not looking for a job.
    - 4: Unemployed person, looking for a job.
    - 5: Employed.
    - 6: Retired.
    - 7: Pensioner.
    - 18: Others.
    - 19: Does not answer.

- Motive of the displacement: Reason why the respondent decided to use the mode of transport described in the route, classified as follows:
    - 1: Travel to home or habitual residence.
    - 2: Stay in a hotel or private address different from their own (family, friends...).
    - 3: Travel to the workplace.
    - 4: Study.
    - 5: Daily shopping.
    - 6: Shopping in general, not daily shopping.
    - 7: Health reasons (visit to medical centre or hospital, etc.).
    - 8: Visit to family or friends.
    - 9: Accompany another person.
    - 10: Work issues.
    - 11: Personal issues.
    - 12: Leisure.
    - 13: Sport, travel to a sports centre, etc.
    - 14: No fixed destination.
    - 15: Journey to second residence.
    - 17: Other reasons.
- Time interval: Time of the day in which the journey was made, based on the end time. It is classified in:
    - 1: Morning (between 06:00 and 11:59).
    - 2: Afternoon (between 12:00 and 17:59).
    - 3: Evening (between 18:00 and 23:59).
    - 4: Night (between 00:00 and 05:59).
- Duration: Time in minutes that has been required to complete the entire journey, with all the combinations described. It is a subjective assessment of the respondent, without any direct measurements.

- Mode: Transport mode used, including non-motorised modes, up to a total of 3 for the same route (for example, on foot to a bus stop, then urban bus to a railway station and a regional train to another municipality). The modes haven been grouped following the criteria mentioned below:
    - 0: Exclusively for non-motorised or motorised modes that are not analysed (urban buses from other municipalities other than Valencia, school discretionary buses, long-distance trains, etc.).
    - 1: One or several of the following public transport modes are used: Valencia urban buses, metro or tramway, interurban buses and commuter rail services. It can also include some of the modes of 0.
    - 2: Combination of the modes included in 1 and 3 (at least one of 1 and one of 3).
    - 3: Use of private vehicles (cars and/or motorcycles) exclusively, or in combination with the modes described in 0.
    - 4: Displacements that combine the commuter rail services and any other of the public transport modes analysed (group 1). These are the users that do not benefit
- Fare zones: Fare zone, as described in section III.i., to which the analysed journey would correspond, depending on the origin provided. Numbers between 1 and 4 will be used for zones A to D, respectively.
- Frequency: Number of repetitions of the described journey over a defined time interval. There will be the following possibilities:
    - 1: Daily (7 days a week).
    - 2: Every working day (5 days a week).
    - 3: Several times a week (estimated at 3 times a week).
    - 4: Once a week (1 time per week).
    - 5: Every 15 days (0,5 days per week).
    - 6: Less frequently/sporadically (estimated at 0,25 times a week).
    - 18: Does not know (estimated at 3 times a week, the average of the other weighted data entries).
    - 19: Does not answer (also estimated at 3 times a week).

- Cost: Cost in euros of the described journey, depending on the methodology defined in the previous sections.

It should be noted that in all cases where there are empty cells (as could happen for example on a journey that only includes two combinations of transport modes, but not a third), the value -999 has been used, to avoid errors with the execution of the program.

iii. Adjustments to the variables and data

First, except for the cost and the duration of the journey, the variables taken into account are categorical. To be able to process them correctly, auxiliary variables will be defined in each case, as can be seen in the annex with the model code.

As an illustrative example, taking the case of the gender of the respondents, a value of 1 is used for men and 2 for women. However, this is not part of a continuous scale as with the cost, with increasing or decreasing values depending on a higher or a lower cost, but a binary option instead: either one is male/female or one is not. To introduce this into the model, the gender variable is divided into two auxiliaries: *male* and *female*. Their value will be 1 when the condition they describe is met (*male* is 1 if the respondent is male, *female* is 1 if the respondent is female) and 0 in the other case.

This is how we proceed with all categorical variables, creating as many auxiliary variables as required. However, in all cases of variables in which an indefinite option such as "Does not know" or "Does not answer" appears among the possible answers, these will be excluded as they does not provide relevant information and may affect the distribution of the rest of the auxiliary variables of that category.

If the model is intended to explain the variations in the modal distribution as a function of cost, it is not useful to use a value of that magnitude in absolute terms, but in relative differences between transport modes. In this case, we will use the difference between public and private modes. In this way, it will be possible to know the probability of an increase in the number of users if the average cost of the journey by public transport is lower than that of the private vehicle. The variable will be named *costdif,* as the difference between the cost of private modes and the cost of public transport.

This leads to a new limitation: trips made by public transport do not have a cost for private transport and vice versa. An equivalent cost must then be defined for each case:

- For trips by public transport, the equivalent private cost would be the result of applying the formula (2) defined in section IV with the duration that the respondent has said.
- For trips in private transport, the equivalent public cost is more complex to obtain. As a first attempt, we will assign the cost of an equivalent trip that any respondent using public transport in that same route has declared (that is, a hypothetical Valencia - Manises journey by car would be assigned an equivalent public cost of someone who has declared to have made the same journey, but for example by metro). This allocation will be done randomly, to avoid introducing a conscious bias in the definition of cost.

  However, to avoid excessively high or low values that would appear if the code assigns the value of, for example, a ticket for pensioners, every entry will be manually checked in a second iteration, modifying the significant deviations. Finally, in those cases where there is no declared equivalent by public transport in the survey, we have chosen to simulate that journey with the help of Google Maps and to manually calculate the total amount for the mode or for the combination of suggested modes. In this case, we will use the average fare previously determined for each mode.

The dependent variable will be named *tpvsvp* and will determine the choice between private and public modes. The use of public transport modes will imply a value of 1, thus being 0 when private vehicles are chosen.

iv. Model execution

The modal distribution, defined by the variable *tpvsvp*, will be iteratively compared with the rest of the possible explanatory variables: day, gender, age range, employment, fare zone, motive, time interval and frequency. Some of these will have a significant influence and will then be preserved; others, on the contrary, will not and will be discarded from the model. The analysis will be carried out with the help of the software known as MPlus, which allows the creation of discrete logit models. To learn more about the specific code used, the reader may consult annex 1.

In order to achieve greater precision and following the logic used in this document, the analysis will be carried out by corridors, determining which factors influence each of them. This will also be done with the unified global database, to contrast these results.

The model will be executed by categories, always comparing the explanatory variables against a reference. This reference will be chosen manually, generally selecting the most representative (if it is evident) or the one with the highest number of responses in that category. However, initially we will always set as basic explanatory variables the cost difference and the duration, in addition to those of the category under consideration. This is done because both variables will be the main vectors that motivate the user to opt for one option or another, and then other parameters such as the time interval or the gender may be added. This decision is validated for the cost difference after executing the model, but the duration is not always representative, so it will consequently be removed where appropriate.

a) Significance of the variables

The first execution of the model will show results by categories of variables (day, gender, employment...). Then, we will look at the statistical representativeness of the results, with an assessment based on the p-value to decide which variables are discarded from the model. The p-value can range between 0 and 1, and represents how likely it is to obtain the sample or study results if a specific hypothesis is true [40].

In this model, we start from the mobility surveys, in which all the previously described variables are included. The initial assumption or null hypothesis (H_0) is the one considered to be true as long as the statistical test is not proven otherwise: the explanatory variable does not influence the modal distribution. Against this, the alternative hypothesis (H_1) would correspond to the opposite: the variable does significantly influence the modal distribution. The model allows to analyse the differences and determining whether it is due to chance or to the representativeness of the alternative hypothesis [41].

The smaller the p-value, the more infrequent that a sample or results such as those studied are given by chance, so H_0 could be rejected and H_1 could be admitted. When setting the threshold, we must determine the smallest value for which the null hypothesis would still be accepted. Therefore, a lower amount than the threshold fixed for the p-value would imply accepting H_1.

$$\begin{cases} \text{if } p_v < \text{threshold} \rightarrow H_1 \text{ is accepted} \\ \text{if } p_v \geq \text{threshold} \rightarrow H_0 \text{ is accepted} \end{cases}$$

The threshold is set based on the reference publication by D. Bakan, *The test of significance in psychological research* [42]. The author proposes that, if the p-value is between 0.1 and 0.9, there would be no reason to suppose that the hypothesis is significant (in this case, to accept the variable) and also suggests setting the limit at 0.05, although this would never be an absolute value. In fact, it is not uncommon to increase it if it is intended to accept more variables in the model so as to avoid losing information because it is excessively strict, as T. Dahiru argues [43]. We have decided to set it to 0.1, establishing three levels for further analysis based on the results:

- Between 0.051 and 0.100, the influence of the variable is admitted, although it will be subject to further analysis. It could be excluded if no consistency is observed in the results.
- Between 0.011 and 0.050, it can be affirmed that the variable influences the modal distribution.
- Between 0.000 and 0.010, the strength of this statement is much greater: the variable appears to be fundamental in the model.

b) Processing phase

The model is programmed to explain the modal distribution with the categorical dependent variable *tpvsvp*, based on the two nominal explanatory variables of duration and cost difference, and also considering the categorical auxiliary variables of the different groups (day, employment, motive...). The MPlus code will be based on .dat files created for this purpose. There will be five files: one per corridor and the fifth one including all of them, so that the results can be compared and calibrated. The program will detect as empty cells those that include the value -999, as specified in the definition of the variables.

The analysis will have the MLR command as an estimator, which allows a maximum likelihood estimate with standard errors and a χ^2 statistical distribution that is robust to non-normality and non-independence of the observations. By doing this, the model can filter results of the variables that are dependent without affecting the final values.

The first iteration, as mentioned, will compare the different values of the same category with a reference one, also adding the cost difference (and the duration where appropriate). This will allow to initially discard all those that exceed the p-value threshold of 0.100. In a second iteration, each variable that has not been discarded will be tested individually, again along with the cost difference and the duration where appropriate. This will introduce a new filter to eliminate those variables that are not significant. Finally, the third iteration will include the joint analysis of all those variables that have passed the previous significance tests, in addition to the cost difference. By means of these three repetitions we will try to determine the really representative and influential variables in the user's decision, being able to obtain conclusions about their behaviour and their impact on the system.

The only exception to this procedure applies if, contrary to the original approach, the duration and/or the cost difference exceeds the p-value of 0.100 in a consistent manner when combined with other variables. This circumstance affects the duration exclusively and in some analysis by corridors. It will then be eliminated from the model, leaving only the cost difference and the variable(s) to be tested in each iteration.

The tables that summarise the results for all five models are included in Annex 2.

c) Assessment of the results

The model has been executed following the previous procedure and all variables have been tested in all corridors. These are the main conclusions that have been obtained:

- The cost difference is the principal variable that explains the modal share and consequently the use of public transport. No matter which corridor or iteration, it will always be strongly significant, as users tend to prioritise modes that do not represent an excessive cost for them. There will be a direct link: if the private vehicle is much more expensive than the public transport modes, users will opt for the latter for their displacements. The estimate has a positive value, so a positive cost difference will tend to increase the use of public transport modes. This is logical, as the cost difference is defined as the cost of the private alternatives – cost of the public modes, so a positive difference means that the latter are less expensive.

  We can also observe the odds ratio, which shows how many times the modal distribution will be incremented if the cost difference increases by a unit (in this case, by 1€). The model is obviously quite sensitive to this variable, with a remarkable increase in all corridors if the cost difference is altered in such a way. This tells us that, for instance, if using the metro is 1€ cheaper than the own private car, the number of users that regularly opt for this option would multiply.

- As opposed to what intuition would tell us, the duration of the trip does not appear to be significant in the determination of the modal distribution, according to the model. This may be because other related variables prevail, such as fare zones, instead of the actual duration of the displacement. Also, given that the values of this variable are subjective and depend on what the respondent perceived, it may not be possible to find a direct relation between this variable and the use of public transport.

- The day of the week does not have an influence on the choice between public transport or private vehicles. The database only includes responses from weekdays, so this may have reduced the variability and no particular link can be observed.

- Gender does impact the choice and this influence appears to be significant. With this model, a woman has around two times more chances to select a public transport mode than a man. This aspect remains rather stable amongst all corridors. This conclusion is not surprising, as gender and public transport are two topics that are correlated and commonly analysed as dependent variables. Indeed, there are many documents at a national [44] and local [45] level that show that women are more prone to use public transport, but this is a tendency which is observed all around the world, and is normally due to the gender roles that are imposed by society. Generally, women tend to be responsible for running errands and for house duties, which imply a larger number of displacements and, at the same time, shorter trips. They also have less own resources and less access to private vehicles. Even though this is more evident in developing countries, the metropolitan area of Valencia still shows these patterns.

- On the contrary, even though there are fares which are specifically designed for the youngest and the oldest users age does not seem a relevant factor, except for the inconclusive result for the elderly in the north-western model. However, it could be deduced that, for travellers older than 65, the use of private vehicles tends gradually to journeys as passengers and not as drivers.

- Regarding the different professional categories, we observe that being a student appears to be relevant in almost all corridors. Those who describe themselves as students favour public transport much more than other categories, which would be rational as there are special discounts for them, they are less prone to own a vehicle than adult employees and educational centres in Valencia, especially universities, are well connected by public transport with many municipalities of the metropolitan area. In two corridors, domestic workers are also a relevant category, also due to their lower access to private vehicles and their lower incomes.

- Regarding zones, there is not a clear conclusion. In some corridors (northern and southern) they show relevant results of the p-value, but not in the others. In any case, for those results which are significant, the correlation with public transport is logical: zones that are further from the capital (C and D) have a negative value for the estimate, which means that it affects negatively to the demand of public transport. These zones normally have lower connectivity and frequencies of the public transport network, that is, a worse service, as well as more expensive fares, so they will be more inclined to opt for their private vehicles.

- With respect to the motives that cause the displacements, we find diverse scenarios, but which are directly proportional to the use of public transport in all cases. Previously, we stated that being a student was a relevant variable. Likewise, when the journey is motivated by an educational purpose, this will also be relevant, for the same reasons.

  It can be interesting to see that in the northern and southern corridors shopping appears as a relevant motive. This may be because the inhabitants of this corridors have a direct access to the main shopping zones of the capital, such as Colon street, with metro lines 3, 7 and 9. These are also the corridors with the highest use of commuter train, which arrives to the city centre, thus, to a commercial area. In addition, the principal shopping malls of the metropolitan area (outside Valencia) are located to the north-west and west, which might explain why in these corridors the motive is not relevant, because people traveling along these corridors do not necessarily go to Valencia by public transport for this purpose.

  Finally, we highlight the fact that medical issues become relevant in some corridors, such as the northern one. A possible explanation for this would be that these municipalities, especially the smallest ones, only have a local health centre or clinic, but require going to the capital for more complex interventions in a hospital. Hospitals in Valencia are easily accessible by public transport, whereas parking in their surroundings is not always easy nor inexpensive.

- The time interval is sometimes representative, especially concerning the evening, which we observe that affects negatively to the probability of choosing a public transport mode. This would be because, as we approach midnight, the public transport service is reduced, so metropolitan travellers will be more inclined to use a private vehicle to go to Valencia instead.
- Frequencies are not a decisive factor in this model. The fact that the journey takes place on a daily basis, on several occasions per week or occasionally does not have a direct influence on the mode that is chosen.

v. Sensitivity of the model to the cost variable

The use of a discrete choice model allows us to understand which variables are relevant when it comes to the analysis of the modal share. Nevertheless, this document focuses on the fare structure and its integration, trying to explain how a change in this structure has a direct impact on the use of the public transport network.

For this reason, the numerical calculation will be done based only on the cost difference variable, modelling it on its own against the explanatory variable of modal share. The other categories and their assessment can be further developed in other studies to explore other possible fare structures or to include special bonus in certain situations or to certain user groups.

Coming back to the equation that explains the probability of an option in a Logit model, we will be able to explain the link between an increase in the use of public transport and the cost of the journey as opposed to the same journey by private vehicles. The expression is based on the deterministic term of the utility function, defined in equation (4). In this case, taking the use of public transport as variable I, it will be necessary to determine coefficients b_0 (a constant that represents the influence of the non-observable features) and b_1 (a weighting coefficient of the cost difference).

We will proceed to calculate the model only with the cost difference as independent variable, so as to obtain the results of the threshold and the estimate, which will be then used in our calculations.

Table 10. Results of the coefficients of the deterministic term V_i.

Corridor	Constant b_0	Coefficient b_1
Northern	-1.368	0.682
North-western	-1.729	0.664
Western	-1.145	0.725
Southern	-1.293	0.684

By applying equation (7), we have that the probability that a user chooses to use public transport over private vehicles according to the cost difference is as follows:

Table 11. Probability of using public transport as a function of the cost difference, by corridors.

Corridor	Probability
Northern	$\mathrm{P(public\ transport)} = \frac{1}{1 + e^{1.368-0.682 \cdot \mathrm{costdif}}}$
North-western	$\mathrm{P(public\ transport)} = \frac{1}{1 + e^{1.729-0.664 \cdot \mathrm{costdif}}}$
Western	$\mathrm{P(public\ transport)} = \frac{1}{1 + e^{1.145-0.725 \cdot \mathrm{costdif}}}$
Southern	$\mathrm{P(public\ transport)} = \frac{1}{1 + e^{1.293-0.684 \cdot \mathrm{costdif}}}$

VI. Proposals to modify the fare structure

The solutions to be proposed must respect the basic premise of this document: to integrate all means of transport within the fare structure and to achieve a lower average cost for the users. Once we know the expressions that define the probability to use public transport over private vehicles according to the cost difference, we can test different scenarios and analyse the response of the system.

The procedure will be as follows: in the first place, we will define the new fare structure, specifying the modifications. These changes will then be applied to the database to obtain the new percentages per corridors, also taking into consideration that the induced demand might be captured. Finally, the new average cost will be calculated and we will be able to assess the efficiency of the proposal.

The analysis will be done to the sample that has been considered during all the statistical modelling phase. This means that the different proposals will not apply the previous formulas to the journeys made by means of transport that have been excluded (walking, cycling, etc.) or to those people which do not have access to a private vehicle, for example.

Three different alternatives will be tested. The first one will be the most conservative, as it will only add some new fares to the fare structure, without modifying the existing ones. This would complete the integration of the system in a simple way, but would have a limited impact. The second one will be a progressive scheme, substituting all passes with a low zonal fare, that would increase in a fixed percentage if more means are used. This would try to find a balance between the expenses to the public administrations and the cost for the user. The third one would be similar to the previous one, but with a flat zonal fare, independent of the means of transport used.

i. Methodology followed

For all the alternatives that we propose, we will need to start by determining which data entries are susceptible to change, that is, which users will adopt the new titles. According to the particularities of each alternative, we will have public transport users that will shift from their current title to the new one and there will also be induced demand, as some private vehicle users will move to the public network.

After having described the proposal, the first step will be to define the method or the assumptions to determine this induced demand. This will require differentiating between the alternatives where we introduce new titles to the existing scheme, with the latter remaining untouched, and where we the titles modify the current fare structure. In the first case, the users will have the option to decide whether they maintain their previous titles or they switch to the ones that have been introduced. In the second case, as the current structure is partially or totally substituted, passengers will no longer be able to use their previous titles.

Afterwards, we will have to simulate the future scenarios by assigning the corresponding titles. The affected data entries will be modified accordingly and, with these new parameters, we will calculate the new average fare per corridors, with formula (1). This result will logically include the titles that have been incorporated to the fare structure, for which we will define individual codes. The methodology and remarks taken into consideration are identical to those in section IV.iii.

With these results, we will be able to compare the alternatives with the current situation. First of all, we will verify if the global average fare of the alternative is lower, which was one of the main objectives of this document. This would mean that the cost that the users of the network have to assume in general terms is not as high as in the current situation. Then, we will estimate the number of journeys that have been incorporated to the public transport network as a consequence of the proposal (induced demand coming from private vehicle users) and we will determine the additional costs for the public operators as a result of a decline in the revenues from the tickets.

The estimation of the difference in the number of journeys can be done by comparing the variation in the percentages of use of the public transport modes with the formulas that have been calculated with Mplus (table 11). These formulas, applied to each data entry, lead to the probability of use of said modes.

However, the global percentage is not the direct average of these values, because they have to be properly weighted to be extrapolated to the entire metropolitan population. Each data entry represents an answer to the survey, but not a daily journey. Every single answer has to be multiplied by the corresponding expansion factor and also by the frequency to be able to compare answers describing daily journeys with those that refer to occasional journeys. The frequency is expressed in terms of days/week according to the values defined in section V.ii. Therefore:

$$\text{Extrapolated value} = \text{Variable} \cdot \mathrm{F_{exp}} \cdot \text{Freq} \quad (8)$$

We will then calculate a weighted average of the percentages multiplied by their corresponding factors (F_{exp} and frequency) for each corridor. Later, we will proceed to determine the percental variation of the use of public transport modes by comparing the current weighted average of the percentages with that of every alternative.

In terms of the financial contribution to be made in order to compensate the additional costs that the alternatives induce, we will also start by using equation (8). We know the title or titles used in each of the answers, as well as their related fare, so it will be possible to extrapolate the values to the metropolitan population by applying the previous factors. We may add up the results by titles and also by corridors, obtaining the total revenues per day and direction according to each of these categories (title and corridor).

The financial contribution is expressed in terms of an annual deficit that has to be covered. Therefore, we will have to sum the previous results of all corridors and multiply them by two factors:

- To have the journeys in both directions, the result should be approximately two times what we have obtained, as we were only considering the trips between a metropolitan municipality and Valencia but not in the other direction.

  Nevertheless, to verify that this is precise, we have checked the value of the weighted proportion of the database after filtering the origin and destination with respect to this database before applying the filter. The result is 1,995.

- As we have applied the frequency to obtain the extrapolated value, we have a result per day. We now have to multiply by 365 to calculate the annual revenue.

The difference between the current situation and the alternatives, once all these steps have been followed, will be the financial deficit generated by each scenario.

ii. Alternative 1: addition of new options to the existing fare structure

Alternative 1 corresponds to a non-disruptive scenario, in which the commuter railway network would be integrated thanks to new titles. These would be similar to the inspired by the current Bono Transbordo and Abono Transporte Mensual, with the choice between a 10-journey ticket or monthly passes. This last option would include reductions for students (15%) and for certain users (25%).

The fares associated to the new titles have been calculated using the aforementioned ones as a reference, but slightly increasing their price to include the commuter rail services. We have also considered the costs of similar options in Madrid and Barcelona. The rest of the fare system would be maintained, so these new titles would be an addition to allow transfers from/to any public transport mode of the metropolitan network. The proposal is as follows:

Table 12. Fare structure for alternative 1.

Title	Description	Fare for 1/2/3/4 zones (incl. VAT)
Global Ticket	10 journeys with transfers	11.00€ / 16.00€ / 20.00€ / 26.00€
Full Pass	Unlimited journeys with transfers for 30 days	48.00€ / 59.00€ / 74.00€ / 96.00€
Youth Full Pass	Full Pass for students	40.50€ / 50.00€ / 63.00€ / 81.50€
Reduced Full Pass	Full Pass for users over 65 years, disabled users or large families	36.00€ / 44.00€ / 55.50€ / 72.00€

a) Adjustment of the demand

In order to simulate the new situation, we will have to refer to a number of hypothesis. Therefore, we will suppose that all travellers who currently use commuter trains plus other public means of transport will use these new fares, as they suppose paying a lower fare and using a single ticket instead of two or more combined. This will not happen if they only use one of the public modes: it would be logical to suppose that they will keep using their current ticket or plan as they do not need a new one that combines several means of transport.

For the modelling, we will suppose that all people that currently use the commuter rail network and other public transport modes will change to the new titles, as they will always imply a lower cost per journey. For the other public transport users, we will adopt the hypothesis that they will not change their tickets, so they will keep purchasing their current ones. Regarding private transport users, we will substitute their public equivalent cost by one of the new titles, according to the proposed scenarios which define the demand that will be captured.

Without any further information about the declared preferences of the passengers, we are not able to determine the exact demand that is induced by the new fare system. Consequently, we will have to propose different scenarios:

- Scenario 1: All private vehicle users who have declared that they do not use public transport due to its high cost or due to the necessity of buying several tickets will now modify their transport mode. This information is present in the database, as private vehicle users have been asked about the reasons why they decide not to use the public transport network. They represent a percentage of around 4% in each corridor, distributed in the following way:

Table 13. Percentage of private vehicle users who do not use public transport modes due to their cost or due to the amount of tickets to be purchased. Source: PMoMe (2018) [30].

Corridor	Northern	North-western	Western	Southern
Percentage	4.2%	4.4%	4.1%	4.0%

- Scenario 2: In this scenario, we will consider a higher induced demand, as it would be more realistic to think that more users could switch to the public transport network in case the fare system is modified. Together with a change in the system, the operators could improve the quality of the network and launch an informational and advertising campaign, which could encourage more potential users to consider using these modes. Therefore, not only would those limited by cost or number of tickets be captured, but also those giving other general reasons such as that the service is uncomfortable or that they are unaware of the service. In an ideal situation, instead of supposing this scenario, we would use the real declared preferences of each user. With the information that we have, this could be seen as an optimistic scenario or a possible upper limit.

Table 14. Percentage of private vehicle users who do not use public transport modes due to the motives specified in the PMoMe database. Source: PMoMe (2018) [30].

Corridor	Northern	North-western	Western	Southern
Percentage	11.8%	10.4%	10.4%	7.2%

In both scenarios, the north-western corridor will remain as it was before, as it does not include any commuter railway line. Therefore, public transport users will maintain their current titles and we will assume that there will not be induced demand, as these new titles would not represent any special advantage if compared to the existing ones for this corridor.

b) Assignment of the new titles

In order to simulate the acquisition of the new titles, we have to formulate a series of hypothesis that will define the behaviour of the users of the proposed fare system. The different titles will be assigned following this procedure:

- For the reassignment between public modes, we will suppose that passengers who used single or multiple journeys tickets will change to the Global Ticket. The other cases will use the Full Pass or any of its variation according to age or social group.

- For former private vehicle users that have been considered as induced demand, we will simulate a distribution of 55% for the Global Ticket and 45% for the Full Pass (with possible variations). These percentages have been obtained by analysing the current equivalent titles for the entire commuter railway network and supposing that this distribution would continue with the new titles.

c) Results

The results show a slight decrease in the global average fare (1.125 vs. 1.16) due to the new title, which supposes that users who were paying several fares to use the commuter rail network and other public modes are now paying a unique fare that is more economical. Nevertheless, the global impact is rather reduced because the concerned users are few and the other titles remain intact. The impact of this scenario is more visible in those corridors which have a greater use of commuter trains (the northern and southern corridors), where the partial average fare decreases more than in the other one. The north-western corridor, as we have said before, will not have any validations of this title by hypothesis.

The other modes remain relatively stable with regard to their average fare. Interurban buses do not vary as this new title is not used in any journey that combines this mode and commuter trains. This is because these two options are normally substitutive and not complementary for longer distances. Urban buses and metro and tramway experiment a small decline.

Table 15. Average fares for alternative 1.1 and variation with respect to the base scenario.

Average fare	**Corridors**				
	General	**Northern**	**North-western**	**Western**	**Southern**
Urban buses	0.89 *-1.68%*	0.95 *-1.07%*	0.82 *0.00%*	0.99 *0.00%*	0.93 *-3.23%*
Metro and tramway	1.06 *-1.26%*	1.00 *0.11%*	0.99 *0.00%*	1.20 *-1.49%*	1.05 *-3.79%*
Interurban buses	1.79 *0.00%*	2.77 *0.00%*	2.44 *0.00%*	1.52 *0.00%*	1.48 *0.00%*
Commuter trains	1.16 *-23.66%*	1.49 *-24.40%*	-	1.16 *-26.46%*	1.03 *-25.32%*
Global	**1.13** ***-3.38%***	**1.20** ***-4.35%***	**1.09** ***0.00%***	**1.22** ***-3.26%***	**1.07** ***-7.96%***

With the second scenario of induced demand, these effects are clearly enhanced and the reduction of the global average fare is noticeable thanks to the contribution of commuter trains, which, as we described in previous sections, were increasing the global fare. It is visible in some corridors, where the value for commuter trains is even lower than that of metro and tramway, and much lower than interurban buses. However, this might indicate that a 10% induced demand in nearly all corridors, even if the service improves in terms of quality and not only in integration of fares and cost, could be seen as excessively optimistic, so we will consider this situation as a best-case scenario.

Table 16. Average fares for alternative 1.2 and variation with respect to base scenario.

Average fare	**Corridors**				
	General	**Northern**	**North-western**	**Western**	**Southern**
Urban buses	0.89 *-1.67%*	0.94 *-2.04%*	0.82 *0.00%*	0.99 *0.00%*	0.90 *-6.38%*
Metro and tramway	1.00 *-6.83%*	0.98 *-1.44%*	0.99 *0.00%*	1.09 *-10.45%*	0.95 *-12.56%*
Interurban buses	1.78 *-0.33%*	2.74 *-1.20%*	2.44 *0.00%*	1.52 *0.00%*	1.48 *0.00%*
Commuter trains	1.08 *-28.77%*	1.24 *-36.72%*	-	0.90 *-43.10%*	0.92 *-33.47%*
Global	**1.08** ***-7.25%***	**1.14** ***-9.08%***	**1.09** ***0.00%***	**1.09** ***-13.04%***	**0.98** ***-15.71%***

iii. Alternative 2: reorganisation of the categories

This proposal would pretend to reorganise the entire system, reducing the number of titles that are internal of each operator and encouraging multimodality whilst at the same time maintaining different options to choose from.

This modification would not affect to single tickets, titles that are addressed to tourists (T1/T2/T3 and VLC Tourist Card) or to specific social groups (Bono Oro, EMT ambTU, EMT Infantil, EMT BP Especial, EMT Mascota, Gent Major and TAT Mobilitat Anual). This is because we would not like to eliminate the simple options for those who want to make a sporadic or touristic use of the network and therefore would not purchase titles that involve combinations, and also to avoid penalising those social groups that currently benefit from very reduced fares.

The other titles will be substituted by two modalities, inspired by the options that we can find in large cities such as Madrid or especially Barcelona: a multiple-journey pass for 10 journeys, conceived for groups of people or infrequent uses, and a monthly ticket with a lower cost per journey, addressed to those who travel by public transport on a regular basis. The intention would be to encourage customer loyalty with this last option, which offers a more economical alternative than all the current multimodal titles and a fare that is almost equal to the least expensive option of any operator.

Table 17. Fare structure for alternative 2.

Title	1 zone	2 zones	3 zones	4 zones
Pass 10	0.90€	1.20€	1.55€	2.10€
30 Days	35.00€	45.00€	60.00€	80.00€
Youth 30 Days	29.75€	38.25€	51.00€	68.00€
Reduced 30 Days	26.00€	33.50€	45.00€	60.00€

a) Adjustment of the demand

We will assume that public transport users will not change their current mode, but will do with respect to the title, as many of the ones that they may be using now will cease to exist. The demand, in global terms, does not need to be adjusted for this type of users, but it will have to be reassigned between titles (see next section).

On the contrary, there will be induced demand in the segment of private vehicle users. In this case, we will not suppose different scenarios, but we will base our hypothesis on the percentages instead. The public equivalent cost for private vehicle users will change because the fare structure has been modified and the cost difference will be updated.

The first decision would be to determine the distribution of new public equivalent costs. For this, we will proceed as we have done in the previous section: we will analyse the current title distribution and add them up by groups according to their future equivalent (Pass 10, 30 Days or all the other unchanged titles). It will then be assumed that this distribution would be maintained in the future scenario, so we will apply the corresponding fares based on the percentages that we have obtained.

Once the public equivalent cost is modified, we can calculate the new total weighted percentage with the average of the individual contributions from formula (8) for the private vehicles. If we compare this to the average percentage obtained for the current situations and only for private vehicles, the difference will be assumed as the induced demand for this alternative. Therefore, for the ulterior modification of the columns describing the titles used, we will have to consider this percental difference affecting the corresponding number of private vehicles, with a random distribution but maintaining, to the extent possible, the distribution between public modes. Once again, without declared preferences we cannot have certainty about the precision of this hypothesis, but this scenario seems justified.

b) Assignment of new titles

The procedure followed in this case will be:

- Those who previously used single tickets or any of the specific passes/subsidised tickets will continue to do so.
- All multiple-journey tickets will be substituted by the Pass 10 of the corresponding number of zones, no matter which mode is analysed. This will also apply to those data entries where there is not enough information (Other/Does not know/Does not answer). The public mode or modes themselves will not be modified.
- Monthly passes and their variations will change to the 30 Days title, maintaining the discounts according to age or social groups if they had any.
- The induced demand applied to private vehicles will mean that the affected data entries will change to a public mode. As we have done before, the distribution will try to be as realistic as possible. This means that we will respect the proportion of single tickets/multiple-journey tickets and monthly passes that existed before and also that we will assign public modes proportionally and being coherent with the journey to be made (e.g. no commuter train journeys will appear in the north-western corridors or no metro titles will be used for a displacement from a municipality that has no access to the metro network).

c) Results

This alternative also achieves a reduction in the global average fare, which is in this case comparable to the one obtained with the optimistic induced demand scenario (alternative 1.2). In this case, the networks that reach longer distances are the most benefitted from a lower fare grading in general terms. That is, citizens from the furthest zones of the metropolitan area are the most benefitted from this change. On the contrary, the values of urban buses experiment a small rise, as fares for 1 zone are a bit higher than the reference value for the Bonobús, the most used title in this mode. However, the global effect is positive, as much more travellers are benefitted by the decrease in the fares for further zones than the ones that may be disfavoured by a small increase.

Table 18. Average fares for alternative 2 and variation with respect to base scenario.

Average fare	**Corridors**				
	General	**Northern**	**North-western**	**Western**	**Southern**
Urban buses	1.02 *8.68%*	1.05 *9.64%*	0.93 *10.94%*	1.00 *5.29%*	0.94 *-1.94%*
Metro and tramway	0.96 *-10.26%*	0.90 *-9.84%*	0.82 *-16.96%*	1.12 *-8.44%*	1.01 *-7.11%*
Interurban buses	1.52 *-14.81%*	2.41 *-13.15%*	2.06 *-15.50%*	1.25 *-17.73%*	1.22 *-17.92%*
Commuter trains	1.21 *-20.09%*	1.61 *-18.31%*	-	1.45 *-8.48%*	1.07 *-22.83%*
Global	**1.08** ***-7.51%***	**1.21** ***-3.90%***	**0.99** ***-8.75%***	**1.16** ***-7.99%***	**1.04** ***-10.53%***

iv. Alternative 3: flat fare

In this case, we propose substituting all existing titles with a flat fare per journey, proportional according to the zones, but allowing transfers between all public modes. This fare would require a wallet-type physical support, such as the TuiN system with the Móbilis card.

Again, the exception to this would be the previous titles that are specifically designed in some networks for some vulnerable social groups, such as the elderly, children, disabled users or families with low incomes. It is the case of Bono Oro, EMT ambTU, EMT Infantil, EMT BP Especial and EMT Mascota (urban bus), Gent Major and TAT Mobilitat Anual (metro/tramway). For any other cases, the reductions that will be applied to the new flat fare will be more beneficial for the customer than the current prices.

The fares that are proposed are slightly more expensive than the lowest existing ones for each zone, but this increase is affordable in all cases and promotes multimodality, as it gives the chance to use all modes, whereas the lowest fares are always specific of a particular mode.

However, for the rest of the cases, the new fares will be significantly lower, which would lead to considerable savings for users, especially for those travelling from longer distances, but in exchange would require higher financial contributions from public bodies.

The fare structure is described in the table below. The costs included are per journey, including possible transfers. We have maintained all the previous reductions for students (youth flat fare, 15% reduction) and for pensioners, large families and people over 65 (reduced flat fare, 25% reduction):

Table 19. Fare structure for alternative 3.

Title	1 zone	2 zones	3 zones	4 zones
Flat fare	0.90€	1.10€	1.45€	1.90€
Youth flat fare	0.77€	0.94€	1.23€	1.62€
Reduced flat fare	0.68€	0.82€	1.13€	1.50€

The price for the flat fare is conceived with the main reference of the most used titles of the existing scheme: Bonobús and Bonometro. This is because the proposal should be tailored to the users' current demand in order for them to adopt the new titles avoiding public criticism. We have also taken Barcelona's recently introduced T-usual as an inspiring reference [46], because it is a similar example of how a metropolitan network can be reorganised and simplified. Nonetheless, in our proposal the furthest zones are also the most benefitted (the difference with the evolution per zones of the T-usual fare assuming 40 journeys per month is evident, even though we must also consider the larger extension of Barcelona's zones). This is because we want to encourage the use of public transport in particular in these zones, which, as we have demonstrated all along the document, have worse connectivity and users are forced to paid higher fares, as well as several titles.

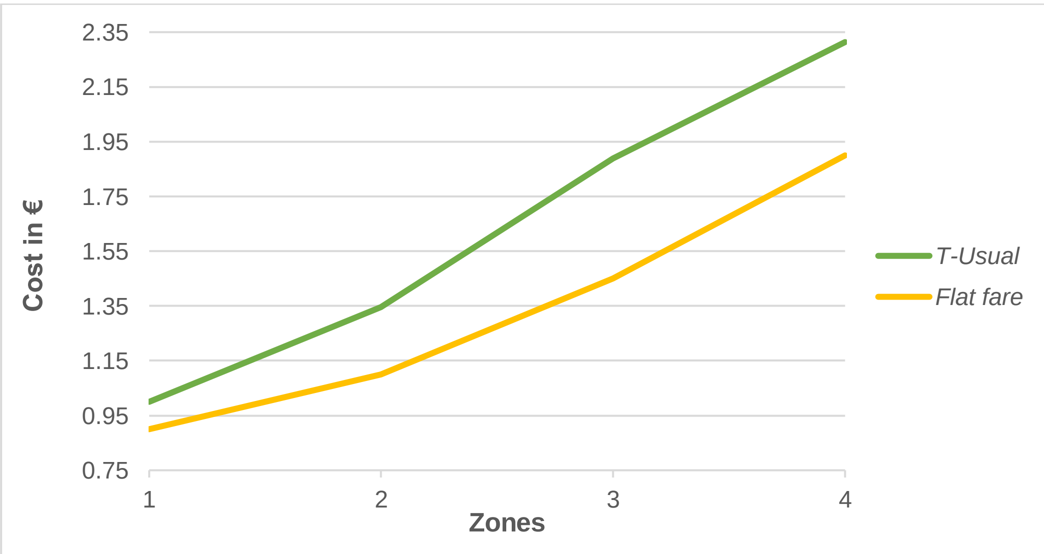

Figure 24. Comparison of Barcelona's T-usual fare per journey and the proposed flat fare. Source: Transport Metropolità de Barcelona (2020) [46].

a) Adjustment of the demand

For the adjustment of the demand, we will proceed in the same way as in the previous alternative. However, we will now have a unique fare (with two possible variations according to age groups), plus the titles with reductions to social groups, instead of three large options. This will apply for both current public transport and private vehicles users, but it will be the equivalent public cost for the latter.

It will not be necessary to determine any distribution percentage with just one title, but we will have to differentiate between age groups, assuming that all those who belong to the youngest or the oldest will benefit from the economic reductions to the title. This will also affect the public equivalent cost of private vehicles users.

The induced demand will be determined with the same procedure as in the previous scenario (difference between the current and the new weighted percentage). The allocation of the public transport titles to the private vehicles users that are considered as induced demand will once again be done randomly.

b) Assignment of the titles

The assignment of the titles will be very similar to the previous alternative, although in this case there will not be a distinction between different types:

- There will no longer be single tickets or any other type that has not been explicitly excluded from the modification (internal subsidised passes such as Bono Oro, Gent Major, etc.). This means that the majority of data entries are susceptible to be changed.

- This fare structure distinguishes between the normal flat fare, the modality conceived for students and the one for the elderly and other social groups. These last two will be assigned according to the age range data included in the database. The other affected entries will all be assigned the normal flat fare, adjusted by zones.

- The induced demand will be treated in the same way as in the previous section, in terms of distribution of the allocated public modes and the proportion of the titles.

c) Results

As one may expect, this is the alternative that achieves the greater reduction in terms of global average fare, thanks to a unique and low flat fare. The effect is particularly remarkable in the southern and northern corridors, where we have greater use of interurban buses and commuter trains, which previously had high fares for long distances.

The trend is similar to the previous alternative: the most benefitted are those living in peripheral areas, while the closest to Valencia and its city centre may be somehow penalised in some specific cases. This is not the norm, as the reader may see with the decreases in the urban buses values in the southern and western corridors, but it may happen as, once again, the flat fare is a little higher than the Bonobús/Bonometro for 1 zone.

In general terms, this alternative has the lowest average fare and the highest percentages of induced demand, therefore effectively promoting the use of public transport in the metropolitan area.

Table 20. Average fares for alternative 3 and variation with respect to base scenario.

Average fare	**Corridors**				
	General	**Northern**	**North-western**	**Western**	**Southern**
Urban buses	0.90 *+0.28%*	0.95 *-1.48%*	0.88 *+7.14%*	0.82 -17.07%	0.83 -13.92%
Metro and tramway	1.06 *-1.26%*	1.01 *1.36%*	1.00 *1.04%*	1.22 *0.49%*	1.01 *-7.66%*
Interurban buses	1.10 *-38.44%*	1.75 *-36.70%*	1.13 *-53.56%*	0.95 *-37.48%*	0.97 *-34.49%*
Commuter trains	1.09 *-28.32%*	1.31 *-33.58%*	-	1.15 *-27.13%*	0.99 *-28.19%*
Global	**1.05** ***-9.82%***	**1.14** ***-8.88%***	**1.04** ***-2.93%***	**1.12** ***-10.76%***	**0.98** ***-15.91%***

v. Comparison between alternatives

As the calculations state, all alternatives proposed achieve a reduction in the average fare and consequently in the cost that the user has to assume to use the public transport network. In these terms, all of them are positive, with the most integration and rationalisation of the titles meaning the least cost at a general level. At the same time, this attracts more users and the induced demand grows, so operators will transport more passengers per year.

Nevertheless, these modifications have a direct effect on the revenues that are generated (see section VI.i.) and may lead to a financial deficit that would have to be covered or subsidised by the Metropolitan Transport Authority.

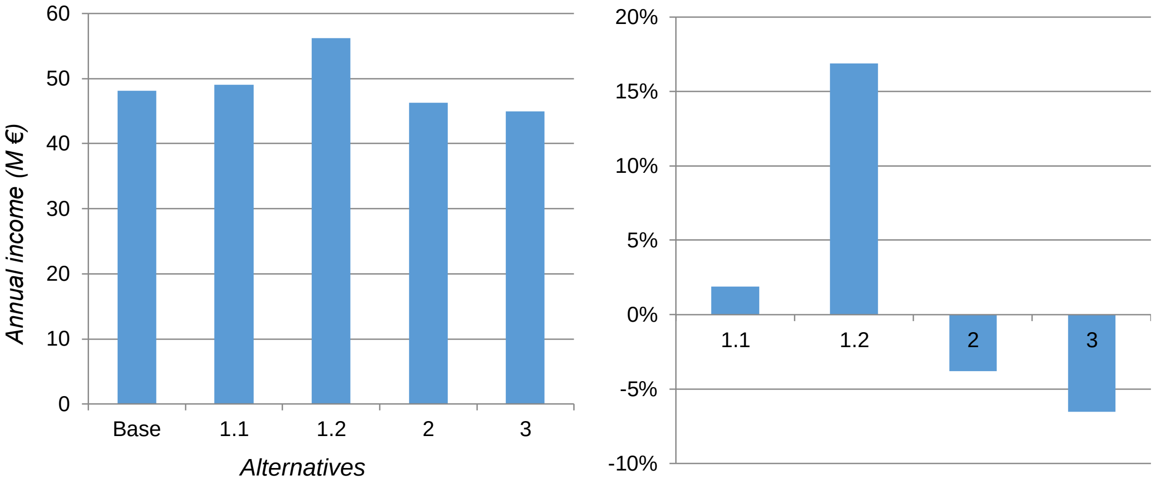

Figure 25. Annual income (in million €) for each alternative and variation with respect to the base scenario.

This is not the case for the first alternative. The reduction in the revenues received exists, as both the Global Ticket and the Full Pass imply a lower fare per journey than combining no matter which commuter train ticket and any other public mode ticket. However, this effect is compensated by the fact that there is induced demand, so additional revenues are generated by new public transport users that were driving their private vehicles before. This is visible when we analyse alternative 1.2, with values for the induced demand of around 10% and a considerable increase in the total revenues.

Alternatives 2 and 3 do show this decline in the annual income. In both cases, nearly all users are affected by the change in fares, which at the same time are considerably lower than the previous equivalent titles (with some minor exceptions in zone A that do not have a remarkable impact in the global results). The induced demand in these two cases is not capable of compensating the huge and generalised reductions. The rationalisation process, which implied a downward adjustment of the vast majority of fares in order to merge them into a single type that adapts to nearly all circumstances, needs to be supplemented with an external financial contribution to cover these effects. The more we unify and lower fares, the higher deficit we will generate in the network, even though the number of users increases. These alternatives could be potentially implemented if there is a political or managerial decision to assume the compensations and subsidies required.

In any case, we must acknowledge that these values and calculations have been applied to a sample, with several limits (internal and imposed) or simplifications adopted by hypothesis. The final result will not be perfect or totally precise. As well as that, it represents the contribution of the trips between a metropolitan municipality and the capital, not the transversal ones or the ones that are internal to the same municipality, a considerable percentage of the EMT network. We decided to focus on metropolitan mobility for this study, as it concerns the majority of displacements and its fare structure showed room for improvement. Consequently, the values that are included in the figures will not coincide with those declared as annual profits by the operators, but will be a part of them instead.

VII. Future scenarios and proposals

These proposals only represent some of the possible options that may be selected to improve the interoperability of the network, to facilitate the displacements for travellers that are currently using several public modes and also to incorporate new users that were previously using private vehicles.

As the reader will understand, these are only some options that may be implemented to enhance the quality and attractiveness of the metropolitan network, but further proposals could be studied. We have tried to guide our alternatives based on three possibilities or integration phases: the first one, where we complete the current system on a short-term basis with the adhesion of the sole transport mode that is not integrated; the second one, a transition phase where we would maintain the structure (single tickets, multiple-journey tickets and monthly passes) but with a standardisation of the fares and conditions for all modes; and the third one, which merges all fares into one, based on a wallet system that enables complete integration and simplification. All of them propose changes to the current system and improve, to a greater or a lesser extent, the conditions for the users.

We have analysed the situation from an economic cost-benefit perspective, comparing the partial and global average fares, which are indicative of the costs to be paid by the user. We have also taken into consideration the annual income that is generated, which allows to measure the part of the revenues for operators that is related to intermunicipal transport to Valencia and, through the difference with the initial situation, the compensations required by the fare integration process. This approach represents a main argument to eventually decide between alternatives, but it could also be complemented with social and environmental data: access to jobs/hospitals/financial centres, greenhouse emissions saved, congestion avoided, etc. This indicators can be translated into a monetary value through the appropriate methodologies, but would require a more in-depth analysis of the subject that exceeds the scope of this document.

In addition, we could continue proposing modifications to the system itself, which are not always related to cost. For example, the last alternative tends towards the final, effective integration of all modes and all fares. One future scenario to consider could be the application of the dynamic fare, as it is done in Washington D.C. This would allow to optimise the proportionality of the fare, eventually leading to either better commercial margin for operators or more adapted prices for users. The definition of this option is rather difficult with the information and with the tools available, and we ignore if the current technological stage would admit this solution (for instance, in buses, where there is no checkout when getting off the vehicle). Therefore, this could remain as a proposition for a further feasibility study.

Another option that could be contemplated would be the application of capping to the last alternative. Capping is setting a monthly limit to avoid excessive expenses for those who need to make several trips per day and to promote an intensive use of the public transport network. Obviously, this means that the total revenues that the operators receive would be reduced and a higher financial allocation should be convened between the Transport Authority and the affected operators. Nevertheless, at the same time this would mean compensating the elimination of the monthly or annual passes, because capping has the same effect through a different approach: in both cases, the titles are more profitable for the users as more journeys take place.

Other possible suggestions would be to look at the outputs of the model and to propose alternatives based on criteria other than the cost. This already exists with reductions based on age groups, for example. However, if we look at the relevance of other variables, we can see that for example gender has an important influence. Women tend to use public transport more than men, this is a tendency that we know and that is showed by the model. As a consequence, we could benefit them by creating a better and safer network for women, with appropriate stops (with lighting, in specific places that do not suppose a risk for women) or even with the possibility to request them at night, as it has been announced in the capital with the Violet Stops [47]. Other possibility would be to adapt the frequencies of the public transport network to the demand peaks of women, which do not always coincide with those of men. As we can observe, there are many different options that may be implemented to promote the use of public transport and to foster customer loyalty from the current users.

In any case, the main limiting factor will be the availability of financial resources. It is fundamental that the Authority of Metropolitan Transport of Valencia receives the necessary funding allocations to develop the missions and objectives that they have defined, which are ambitious and concern several action lines. The Authority will surely benefit from the collaboration of the concerned municipalities, regional entities and the State, not only in terms of budget, but also to the institutional strengthening, endorsement and legislative support throughout all this process of adaptation of the current network to a more integrated scheme. The more support the process has, at all levels, the more adapted and integrated solution will be able to be implemented.

VIII. Conclusions

This document begins with an introduction that delimits the context and the scope of the study that will be carried out, stating the main objective from the very beginning: how can we adapt the metropolitan public transport network of Valencia to become a more attractive option and to gain users against the private vehicle? This section clearly shows that the focus will be at the metropolitan area level, considering the four main modes of public transport (urban buses, metro/tramway, interurban buses and commuter trains) and the main private vehicles (automobiles and motorcycles). In addition, this section highlights the recent efforts in the coordination of all operators following the creation of the Authority of Metropolitan Transport of Valencia, which must be provided with the necessary resources to meet the ambitious objective of rationalising and integrating passenger transportation inside the Valencian Community.

Afterwards, we show the main mobility trends in the metropolitan area of Valencia and their evolution over the last years, carrying out a comparative analysis with cities and metropolitan areas of similar extension nationwide. The situation in Valencia is rather unique: the climate and the urbanism seem to favour journeys by foot and, in recent years, by bicycle and scooters, beyond other cities which have a greater difficulty due to their sloped urban context. However, the private vehicle continues to have a privileged position, although there is a fairly dense public transport network with good coverage at the metropolitan level.

One of the main obstacles seems to reside in the existing fare system, which currently does not seem to enhance the interconnection between the different modes, in addition to penalising the displacements of those who reside at a greater distance from the city, who in many cases are forced to pay higher rates and even to acquire several titles for their trips to the capital. Nowadays, integrated titles do not represent an interesting solution. Multiple-journey tickets are predominant (Bonobús and Bonometro, fundamentally) against these integrated titles, which would allow transfers in different public modes. Their incidence in the network is very small, a trend that has not been reversed in recent years.

To this we must add the interesting case of commuter trains, which, unlike the other three public modes considered, do not benefit from any integrated title. Likewise, the zoning of commuter trains differs from those of the other operators, mainly due to the great extension of the network and its planning and operation at a national level. However, it should be noted that some steps have been taken in the right direction with the elimination of magnetic cards and the adoption of a contactless system, as well as with the preparation of a fare system that could be compatible or easily replaceable in the framework of a future integration scenario.

In addition, the document has mainly focused on radial mobility towards the capital, since it represents most of the metropolitan displacements made. Transversal mobility, as we have seen, is residual, due to the strong presence of Valencia as an attractor pole at all levels (economic, labour, leisure, commercial...) and due to the configuration of the network, which privileges these displacements over the few transversal alternatives that may exist.

The study has addressed the issues of modelling and has proposed several scenarios of modifications in the fare system. The problem could have been approached from other perspectives, such as changing the zone limits or definition or merging some of them. Nevertheless, seeing the disparity and the little use of integrated titles at present, it has been considered convenient to opt for the modification and simplification of the fare system. The analysis has been carried out by means of a discrete choice model, which allows to simulate the users' behaviour and decisions when choosing one of the two types of transport modes. In our model, the main variable that will motivate this decision will be the cost (or the difference between the costs of both types of transport modes), although this does not mean that there are no other elements that can also affect, as it has been shown throughout the previous sections.

Several alternatives have been proposed, from the most conservative to the most ambitious. For these scenarios to become real, a sustained support from public entities will be required. The Metropolitan Transport Authority, recently created, requires strengthening to monitor this integration process and, above all, the required funding must be allocated, as this process may penalise the revenues obtained by the operators. We have showed that the most ambitious scenarios, where we rationalise the fares to the maximum extent, also require lowering them or users from the closest zones would not be willing to adopt them as the final cost could be higher. Consequently, if a low global fare is adopted, the revenues previously generated by those validating their tickets in a further station are lost and this deficit has to be covered. This is why the document shows a range of possible alternatives, all of them realistic and implementable, which would be the base in a future decision process.

All along this study, the main limitation has been the lack of information available to define scenarios. We must recognise the efforts made in the PMoMe to have an extensive and updated database, which allows to perform some initial operations. However, the priorities of each of the operators regarding a future integration scenario are not publicly known, beyond the motto of achieving a unified and simplified system. It is also not always easy to access information about the main conditioning issues in this process. Not only legislative and institutional aspects may appear, logical in a process of this type, but there could be setbacks in terms of technology or distribution of revenues, which are not analysed in this document due to the complexity and extent of these topics, clearly exceeding its scope.

Also, the implementation of the unified system must be accompanied by a harmonisation in terms of vending equipment and ticket validation. Fortunately, in recent years there has been a tendency towards a standard of contactless cards in all operators, with three of them currently using a Móbilis card. It has been confirmed that, in the future, the card will be interoperable between all operators, as they will all use a common technology (Móbilis 2.0). During the first phases, this will allow the coexistence of internal titles of each operator with a possible unified fare/title, a situation which would guarantee the viability of the proposals in this document.

The distribution of the revenues that are generated is also an issue to consider, since the modification of the fares would affect the settlement payments and compensations to be made to each operator. Therefore, it would be necessary to renegotiate the agreements to avoid the appearance of important losses that would discourage operators to continue the integration process. Nonetheless, the complexity of this topic has advised not to analyse it in depth, but to rather mention it as one of the possible future lines of work to complement this study.

In short, the analysis and modelling of metropolitan mobility is a task that requires a good understanding of the multitude of intervening factors, factors which are interrelated and which do not always have a direct and clear impact. As the model itself shows, there are many variables beyond the cost difference itself that may impact the user's decision.

This document aims to show the undeniable need for a harmonization in the public transport network of the metropolitan area of Valencia, which is nowadays far from being able to provide a better and more attractive option than private vehicles, especially for those living in peripheral areas. It is undeniable that the system requires harmonising titles and fares between operators. With simplicity, rationality and economy the public transport network will surely reach a better position in the near future. The increasing trend towards a more sustainable, collective way of transport indicates so.

It is therefore an important task for decision-makers to consider all the variables involved in the process so as to find a solution that meets the requirements of all the people involved, trying to find a balance between the sustainability of the system and the promotion of public transport in all the metropolitan area. As civil engineers, it is our duty to help in this process and to contribute to the development of our societies.

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ANNEX 1.- Code used for the discrete choice model

The objective of this annex is to illustrate how the discrete choice models were programmed. We will show the code used for one of the corridors, which has been replicated for the others but changing the .dat file specified as source. The code follows the format required by the software Mplus.

```
INPUT
DATA:
    File is Input norte.dat;
DEFINE:
    monday = 0; if (day == 1) then monday = 1;
    tuesthur = 0; if (day == 2 OR day == 3 OR day == 4) then tuesthur = 1;
    friday = 0; if (day == 5) then friday = 1;
    male = 0; if (gender == 1) then male = 1;
    female = 0; if (gender == 2) then female = 1;
    ag5to17 = 0; if (agerange == 1) then ag5to17 = 1;
    ag18to44 = 0; if (agerange == 2) then ag18to44 = 1;
    ag45to64 = 0; if (agerange == 3) then ag45to64 = 1;
    ag65to79 = 0; if (agerange == 4) then ag65to79 = 1;
    ag79plus = 0; if (agerange == 5) then ag79plus = 1;
    job1 = 0; if (job == 1) then job1 = 1;
    job2 = 0; if (job == 2) then job2 = 2;
    job3 = 0; if (job == 3) then job3 = 3;
    job4 = 0; if (job == 4) then job4 = 4;
    job5 = 0; if (job == 5) then job5 = 5;
    job6 = 0; if (job == 6) then job6 = 6;
    job7 = 0; if (job == 7) then job7 = 7;
    student = 0; if (job1 == 1) then student = 1;
    domwork = 0; if (job2 == 2) then domwork = 1;
    unempl = 0; if (job3 == 3 OR job4 == 4) then unempl = 1;
    employed = 0; if (job5 == 5) then employed = 1;
    pension = 0; if (job6 == 6 or job7 == 7) then pension = 1;
    solopub = 0; if (pubpriv == 1 OR pubpriv == 4) then solopub = 1;
    solopriv = 0; if (pubpriv == 3) then solopriv = 1;
    if (solopriv == 1 AND hascar == 1 AND origin == 154 AND destin < 187 AND destin /= 154 AND
    destin /= 155) then tpvsvp = 0;
    if (solopriv == 1 AND hascar == 1 AND origin == 155 AND destin < 187 AND destin /= 154 AND
    destin /= 155) then tpvsvp = 0;
    if (solopriv == 1 AND hascar == 1 AND origin > 186 AND destin < 187 AND destin /= 154 AND destin
    /= 155) then tpvsvp = 0;
    if (solopub == 1 AND hascar == 1 AND origin == 154 AND destin < 187 AND destin /= 154 AND
    destin /= 155) then tpvsvp = 1;
    if (solopub == 1 AND hascar == 1 AND origin == 155 AND destin < 187 AND destin /= 154 AND
    destin /= 155) then tpvsvp = 1;
    if (solopub == 1 AND hascar == 1 AND origin > 186 AND destin < 187 AND destin /= 154 AND destin
    /= 155) then tpvsvp = 1;
    zoneA = 0; if (zonetar == 1) then zoneA = 1;
    zoneB = 0; if (zonetar == 2) then zoneB = 1;
    zoneC = 0; if (zonetar == 3) then zoneC = 1;
    zoneD = 0; if (zonetar == 4) then zoneD = 1;
```

origmot1 = 0; if (origmot == 1 OR origmot == 2 OR origmot == 15) then origmot1 = 1;
origmot2 = 0; if (origmot == 3 OR origmot == 4) then origmot2 = 1;
origmot3 = 0; if (origmot == 5 OR origmot == 6) then origmot3 = 1;
origmot4 = 0; if (origmot == 7) then origmot4 = 1;
origmot5 = 0; if (origmot == 8 OR origmot == 9) then origmot5 = 1;
origmot6 = 0; if (origmot == 10 OR origmot == 11) then origmot6 = 1;
origmot7 = 0; if (origmot == 12 OR origmot == 13 OR origmot == 14) then origmot7 = 1;
home = 0; if (origmot1 == 1) then home = 1;
workstu = 0; if (origmot2 == 1) then workstu = 1;
shop = 0; if (origmot3 == 1) then shop = 1;
doctor = 0; if (origmot4 == 1) then doctor = 1;
visit = 0; if (origmot5 == 1) then visit = 1;
affairs = 0; if (origmot6 == 1) then affairs = 1;
leisure = 0; if (origmot7 == 1) then leisure = 1;
morning = 0; if (timeslot == 1) then morning = 1;
aftnoon = 0; if (timeslot == 2) then aftnoon = 1;
evening = 0; if (timeslot == 3) then evening = 1;
night = 0; if (timeslot == 4) then night = 1;
frec1 = 0 ; if (frec == 1) then frec1 = 1;
frec2 = 0 ; if (frec == 2) then frec2 = 1;
frec3 = 0 ; if (frec == 3) then frec3 = 1;
frec4 = 0 ; if (frec == 4) then frec4 = 1;
frec5 = 0 ; if (frec == 5) then frec5 = 1;
frec6 = 0 ; if (frec == 6) then frec6 = 1;
everyday = 0; if (frec1 == 1) then everyday = 1;
workday = 0; if (frec2 == 1) then workday = 1;
sevdays = 0; if (frec3 == 1) then sevdays = 1;
onceweek = 0; if (frec4 == 1) then onceweek = 1;
ev15days = 0; if (frec5 == 1) then ev15days = 1;
seldom = 0; if (frec6 == 1) then seldom = 1;

VARIABLE:

names are id day gender agerange job origin destin pubpriv triptype zonetar cost costpub costpriv difcost hascar origmot destmot timeslot duration mode1 line1 ticket1 occup1 mode2 line2 ticket2 occup2 mode3 line3 ticket3 occup3 frec;

usevariables are (INTRODUCE VARIABLES TO TEST) tpvsvp;

categorical is tpvsvp;

missing are all (-999);

ANALYSIS:

estimator = mlr;

OUTPUT:

standardized;

MODEL:

tpvsvp ON (INTRODUCE VARIABLES TO TEST);

INPUT_END

ANNEX 2.- Results of the variables with an iterative process

The following annex includes the numerical results given by the program Mplus for each corridor and for the joint sample, merging all data from the different corridors. The procedure used has been explained in section V.iv.b). Processing phase.

In order to organise all this information and to present it in a simpler way, five tables have been prepared. In each one of them, the results are classified by groups of variables, indicating the reference variable in brackets after the name of the category.

A visual colour code has been applied to facilitate the comprehension of the results: the digits without brackets correspond to the first iteration, single brackets refer to the second and double brackets include the results from the final iteration. Additionally, if the final result has a p-value over 0.100, the cell will be shaded in red. If the p-value is between 0.051 and 0.100, the shading will be dark yellow and the result will be followed by a single asterisk (*). In the cases where the p-value is between 0.011 and 0.050, the cell will be shaded in light yellow and two asterisks (**) will be included. Finally, if the p-value is lower than 0.010, green will be used as the cell colour, together with three asterisks (***).

The code also includes an alert ([a]) in some cases as there is no sample to be analysed and therefore this variable cannot be processed. This affects the journeys during the night in some corridors.

What we can observe is that the global model shows an important amount of significant values, which is influenced by the significant values of each corridor. Basically, if a variable appears to be significant in one corridor but not in the others, there global model will mark it as significant too. That is one of the reasons why an analysis per corridors can lead to much more detailed conclusions.

Also, it should be stated that if a specific variable appears not to be significant because the p-value is superior to the result that has been fixed as threshold, it would not necessarily mean that the variable is not significant in real life, but that this correlations have not been captured by the sample in the survey and, therefore, the model cannot show them. Further measures and a larger sample would surely help to refine the model and have more accurate results.

Table 21. Results of the global model.

Variables		P-Value	Estimate	Odds Ratio
Cost difference		0.000 ((0.000))***	0.548 ((0.268))	1.730 ((1.307))
Duration		0.009 ((0.000))***	0.013 ((0.037))	1.013 ((1.037))
Day (Tuesday-Thursday)	Monday	0.290	0.110	1.116
	Friday	0.570	0.059	1.060
Gender (man)	Woman	0.000 ((0.000))***	0.767 ((0.771))	2.153 ((2.162))
Age (From 18 to 44 years old)	From 5 to 17 years old	0.003 (0.001) ((0.104))	0.948 (1.026) ((0.574))	2.581 (2.790) ((1.775))
	From 45 to 64 years old	0.008 (0.000) ((0.123))	-0.233 (-0.295) ((0.167))	0.792 (0.745) ((1.182))
	From 65 to 79 years old	0.080 (0.009) ((0.075))*	0.235 (0.333) ((0.332))	1.264 (1.395) ((1.394))
	More than 79 years old	0.225	-0.506	0.603
Employment (employed)	Student	0.000 (0.000) ((0.000))***	1.266 (1.046) ((1.095))	3.546 (2.846) ((2.989))
	Domestic work	0.000 (0.000) ((0.004))***	1.177 (0.841) ((0.616))	3.243 (2.319) ((1.852))
	Unemployed	0.000 (0.086) ((0.104))	0.622 (0.265) ((0.522))	1.862 (1.303) ((1.685))
	With pension	0.000 (0.082) ((0.115))	0.568 (0.226) ((0.418))	1.765 (1.253) ((1.519))
Zone (zone B)	Zone A	0.000 (0.000) ((0.000))***	0.713 (0.834) ((0.663))	2.040 (2.302) ((1.940))
	Zone C	0.000 (0.000) ((0.000))***	-1.181 (-1.000) ((-1.264))	0.307 (0.368) ((0.282))
	Zone D	0.000 (0.015) ((0.000))***	-0.773 (-0.364) ((-0.872))	0.462 (0.695) ((0.418))

Motive (travel to home or habitual residence)	Work	0.000 (0.039) ((0.074))*	0.609 (-0.180) ((0.423))	1.839 (0.836) ((1.526))
	Study	0.000 (0.000) ((0.000))***	1.722 (1.134) ((0.902))	5.596 (3.107) ((2.463))
	Shopping	0.000 (0.000) ((0.000))***	1.525 (0.850) ((1.175))	4.593 (2.339) ((3.237))
	Medical issues	0.000 (0.006) ((0.001))***	1.194 (0.493) ((0.693))	3.300 (1.637) ((2.000))
	Visit/going with somebody	0.022 (0.039) ((0.186))	0.415 (-0.334) ((0.264))	1.514 (0.716) ((1.303))
	Personal/professional issues	0.000 (0.078) ((0.000))***	0.964 (0.258) ((0.686)))	2.623 (1.295) ((1.986))
	Leisure/sports	0.000 (0.075) ((0.110))	1.099 (0.397) ((0.994))	3.001 (1.487) ((2.702))
Time interval (morning)	Afternoon	0.000 (0.014) ((0.008))***	-0.441 (-0.224) ((-0.341))	0.643 (0.800) ((0.711))
	Evening	0.000 (0.000) ((0.000))***	-0.881 (-0.720) ((-0.663))	0.415 (0.487) ((0.515))
	Night	0.052 (0.118)	-1.436 (-1.154)	0.238 (0.315)
Frequency (everyday)	Working days	0.471	-0.097	0.907
	Several days	0.163	0.223	1.250
	Once per week	0.945	0.015	1.015
	Every 15 days	0.833	0.067	1.069
	Occasionally	0.187	0.211	1.235

Table 22. Results for the model of the northern corridor.

Variables		P-Value	Estimate	Odds Ratio
Cost difference		0.000 ((0.000))***	0.732 ((0.676))	2.079 ((1.966))
Duration		0.658	-0.005	0.995
Day (Tuesday-Thursday)	Monday	0.579	0.106	1.111
	Friday	0.944	-0.014	0.986
Gender (man)	Woman	0.025 ((0.006))***	0.345 ((0.389))	1.412 ((1.688))
Age (From 18 to 44 years old)	From 5 to 17 years old	0.945	-0.030	0.971
	From 45 to 64 years old	0.775	-0.049	0.952
	From 65 to 79 years old	0.745	0.076	1.079
	More than 79 years old	0.124	-0.944	0.389
Employment (employee)	Student	0.000 (0.001) ((0.156))	0.947 (0.740) ((0.392))	2.578 (2.097) ((1.479))
	Domestic work	0.181	0.437	1.549
	Unemployed	0.010 (0.085) ((0.138))	0.710 (0.456) ((0.440))	2.033 (1.577) ((1.553))
	With pension	0.030 (0.345)	0.427 (0.173)	1.533 (1.188)
Zone (zone B)	Zone A	0.001 (0.006) ((0.001))***	-1.367 (-1.095) ((-1.318))	0.255 (0.335) ((0.268))
	Zone C	0.000 (0.001) ((0.000))***	-1.301 (-1.051) ((-1.369))	0.272 (0.350) ((0.254))
	Zone D	0.000 (0.009) ((0.000))***	-0.782 (-0.544) ((-0.973))	0.457 (0.580) ((0.378))
Motives (travel to home or habitual residence)	Work	0.390	0.187	1.206
	Study	0.000 (0.000) ((0.000))***	1.893 (1.542) ((1.613))	6.636 (4.675) ((5.020))
	Shopping	0.000 (0.016) ((0.002))***	1.286 (0.806) ((1.121))	3.617 (2.238) ((3.068))
	Medical issues	0.000 (0.003) ((0.002))***	1.443 (0.972) ((1.028))	4.234 (2.643) ((2.796))
	Visit/going with somebody	0.209	0.394	1.483

	Personal/professional issues	0.742	0.114	1.121
	Leisure/sports	0.033 (0.315)	0.907 (0.399)	2.477 (1.490)
Time interval (morning)	Afternoon	0.057	-0.334	0.716
	Evening	0.000 (0.001) ((0.026))**	-0.835 (-0.719) ((-0.510))	0.434 (0.487) ((0.601))
	Night	a	a	a
Frequency (everyday)	Working days	0.140	-0.374	0.688
	Several days	0.124	0.438	1.550
	Once per week	0.032 (0.026) ((0.018))**	-0.997 (-0.907) ((-1.052))	0.369 (0.404) ((0.349))
	Every 15 days	0.101	-1.076	0.341
	Occasionally	0.442	0.226	1.253

Table 23. Results for the model of the north-western corridor.

<table>
<tr><th colspan="2">Variables</th><th>P-Value</th><th>Estimate</th><th>Odds Ratio</th></tr>
<tr><td colspan="2">Cost difference</td><td>0.000
((0.000))***</td><td>0.489
((0.461))</td><td>1.630
((1.585))</td></tr>
<tr><td colspan="2">Duration</td><td>0.031
((0.030))**</td><td>0.020
((0.020))</td><td>1.020
((1.020))</td></tr>
<tr><td rowspan="2">Day (Tuesday-Thursday)</td><td>Monday</td><td>0.575</td><td>0.121</td><td>1.129</td></tr>
<tr><td>Friday</td><td>0.594</td><td>-0.109</td><td>0.896</td></tr>
<tr><td>Gender (man)</td><td>Woman</td><td>0.000
((0.000))***</td><td>0.742
((0.797))</td><td>2.100
((2.218))</td></tr>
<tr><td rowspan="4">Age
(From 18 to 44 years old)</td><td>From 5 to 17 years old</td><td>0.398</td><td>-0.370</td><td>0.691</td></tr>
<tr><td>From 45 to 64 years old</td><td>0.008
(0.001)
((0.835))</td><td>-0.490
(-0.609)
((0.048))</td><td>0.613
(0.544)
((1.049))</td></tr>
<tr><td>From 65 to 79 years old</td><td>0.003
(0.000)
((0.000))***</td><td>0.795
(0.994)
((1.400))</td><td>2.214
(2.702)
((4.055))</td></tr>
<tr><td>More than 79 years old</td><td>0.994</td><td>-0.006</td><td>0.994</td></tr>
<tr><td rowspan="4">Employment
(employed)</td><td>Student</td><td>0.000
(0.000)
((0.000))</td><td>1.550
(1.255)
((1.508))</td><td>4.711
(3.508)
((4.516))</td></tr>
<tr><td>Domestic work</td><td>0.001
(0.017)
((0.038))**</td><td>1.560
(1.075)
((0.976))</td><td>4.759
(2.931)
((2.655))</td></tr>
<tr><td>Unemployed</td><td>0.054
(0.612)</td><td>0.697
(0.179)</td><td>2.009
(1.196)</td></tr>
<tr><td>With pension</td><td>0.000
(0.016)
((0.105))</td><td>1.011
(0.571)
((0.594))</td><td>2.748
(1.771)
((1.812))</td></tr>
<tr><td rowspan="2">Zone
(zone B)</td><td>Zone C</td><td>0.000
(0.000)
-</td><td>-1.321
(-1.107)
-</td><td>0.267
(0.331)
-</td></tr>
<tr><td>Zone D</td><td>0.000
(0.007)
((0.012))**</td><td>-2.023
(-1.482)
((-1.530))</td><td>0.132
(0.227)
((0.217))</td></tr>
<tr><td rowspan="4">Motive
(travel to home or habitual residence)</td><td>Work</td><td>0.915</td><td>0.025</td><td>1.025</td></tr>
<tr><td>Study</td><td>0.000
(0.000)
((0.693))</td><td>1.053
(0.846)
((0.125))</td><td>2.866
(2.330)
((1.134))</td></tr>
<tr><td>Shopping</td><td>0.018
(0.069)
((0.286))</td><td>0.991
(0.711)
((0.437))</td><td>2.693
(2.036)
((1.548))</td></tr>
<tr><td>Medical issues</td><td>0.061</td><td>0.798</td><td>2.221</td></tr>
</table>

		(0.198)	(0.513)	(1.671)
	Visit/going with somebody	0.222	0.411	1.508
	Personal/professional issues	0.310	0.356	1.427
	Leisure/sports	0.074 (0.274)	0.669 (0.380)	1.953 (1.463)
Time interval (morning)	Afternoon	0.541	0.116	1.123
	Evening	0.590	-0.119	0.888
	Night	a	a	a
Frequency (everyday)	Working days	0.492	-0.182	0.834
	Several days	0.440	0.239	1.269
	Once per week	0.923	-0.043	0.958
	Every 15 days	0.264	0.685	1.984
	Occasionally	0.735	0.111	1.117

Table 24. Results for the model of the western corridor.

Variables		P-Value	Estimate	Odds Ratio
Cost difference		0.000 ((0.000))***	0.733 ((1.224))	2.082 ((3.402))
Duration		0.935	-0.001	0.999
Day (Tuesday-Thursday)	Monday	0.642	0.107	1.112
	Friday	0.142	0.338	1.402
Gender (man)	Woman	0.001 ((0.000))***	0.661 ((0.781))	1.936 ((2.184))
Age (From 18 to 44 years old)	From 5 to 17 years old	0.981	0.009	1.009
	From 45 to 64 years old	0.107	-0.313	0.731
	From 65 to 79 years old	0.584	0.158	1.171
	More than 79 years old	0.877	0.135	1.145
Employment (employed)	Student	0.000 (0.002) ((0.000))***	0.991 (0.779) ((1.308))	2.693 (2.180) ((3.698))
	Domestic work	0.000 (0.001) ((0.007))***	1.869 (1.636) ((1.641))	6.484 (5.135) ((5.162))
	Unemployed	0.206	0.402	1.494
	With pension	0.088 (0.628)	0.421 (0.113)	1.524 (1.120)
Zone (zone B)	Zone A	0.222	0.475	1.609
	Zone C	0.707	-0.104	0.901
	Zone D	0.230	0.276	1.317
Motive (travel to home or habitual residence)	Work	0.000 (0.017) ((0.060))*	1.793 (0.457) ((0.863))	6.010 (1.302) ((2.370))
	Study	0.000 (0.019) ((0.911))	2.090 (0.681) ((-0.051))	8.087 (1.975) ((0.950))
	Shopping	0.000 (0.203)	1.923 (0.463)	6.840 (1.588)
	Medical issues	0.000 (0.240)	1.9156 (0.453)	6.784 (1.573)
	Visit/going with somebody	0.007 (0.349)	1.171 (-0.335)	3.224 (0.715)
	Personal/professional issues	0.000 (0.118)	1.889 (0.451)	6.611 (1.570)
	Leisure/sports	0.060	2.359	10.577

		(0.074) ((0.102))	(0.912) ((1.389))	(2.489) ((4.010))
Time interval (morning)	Afternoon	0.003 (0.101)	-0.632 (-0.336)	0.531 (0.715)
	Evening	0.000 (0.000) ((0.005))***	-1.245 (-1.021) ((-0.821))	0.288 (0.360) ((0.440))
	Night	a	a	a
Frequency (everyday)	Working days	0.982	0.007	1.007
	Several days	0.917	-0.041	0.960
	Once per week	0.007 (0.001) ((0.000))***	1.215 (1.191) ((1.389))	3.371 (3.289) ((4.011))
	Every 15 days	0.416	0.626	1.870
	Occasionally	0.844	0.071	1.074

Table 25. Results for the model of the southern corridor.

Variables		P-Value	Estimate	Odds Ratio
Cost difference		0.032 ((0.000))***	0.249 ((0.606))	1.283 ((1.832))
Duration		0.000 -	0.044 -	1.045 -
Day (Tuesday-Thursday)	Monday	0.541	0.127	1.136
	Friday	0.148	0.289	1.335
Gender (man)	Woman	0.000 ((0.000))***	1.132 ((1.230))	3.101 ((3.420))
Age (From 18 to 44 years old)	From 5 to 17 years old	0.189	1.168	3.216
	From 45 to 64 years old	0.113	-0.268	0.765
	From 65 to 79 years old	0.808	-0.075	0.928
	More than 79 years old	a	a	a
Employment (employed)	Student	0.000 (0.000) ((0.000))**	1.427 (1.280) ((1.754))	4.168 (3.598) ((5.778))
	Domestic work	0.001 (0.008) ((0.188))	1.486 (1.182) ((0.638))	4.418 (3.262) ((1.892))
	Unemployed	0.195	0.468	1.596
	With pension	0.172	0.357	1.429
Zone (zone B)	Zone C	0.000 (0.000) ((0.004))	-1.432 (-1.345) ((-0.759))	0.239 (0.261) ((0.468))
	Zone D	0.025 (0.163)	-1.156 (-0.701)	0.315 (0.496)
Motive (travel to home or habitual residence)	Work	0.000 (0.866)	0.957 (-0.029)	2.603 (0.971)
	Study	0.000 (0.000) ((0.549))	2.055 (1.268) ((0.256))	7.804 (3.555) ((1.292))
	Shopping	0.000 (0.000) ((0.000))***	2.360 (1.516) ((1.566))	10.591 (4.552) ((4.789))
	Medical issues	0.017 (1.000)	0.954 (0.000)	2.595 (1.000)
	Visit/going with somebody	0.680	-0.194	0.823
	Personal/professional issues	0.000 (0.005)	1.654 (0.773)	5.227 (2.166)

		((0.000))***	((1.185))	((3.271))
	Leisure/sports	0.032 (0.816)	1.066 (0.111)	2.904 (1.117)
Time interval (morning)	Afternoon	0.000 (0.001) ((0.000))***	-0.937 (-0.641) ((-1.020))	0.392 (0.527) ((0.360))
	Evening	0.000 (0.000) ((0.000))***	-1.510 (-1.213) ((-1.296))	0.221 (0.297) ((0.274))
	Night	0.868	0.136	1.146
Frequency (everyday)	Working days	0.322	0.263	1.300
	Several days	0.693	0.133	1.142
	Once per week	0.503	0.308	1.361
	Every 15 days	0.740	0.210	1.234
	Occasionally	0.131	0.491	1.635

ANNEX 3.- Tickets and fares for the base scenario and the alternatives

We will now show the results of the number of tickets and passes that have been validated in each alternative, associating a fare to them and extrapolating a total result of journeys and revenues thanks to the expansion factors. As including all corridors for the base scenario and the four alternatives could be confusing, we have decided to group them and to display global results per modes and alternatives.

The tables will show the titles for each operator that have been validated at least once according to the PMoMe database, so this does not mean that, if a ticket or pass does not appear, it is no longer in use. Again, we have tried to simplify the display of the results.

We have used a code with asterisks to indicate that an integrated title is used in more than one mode:

- If the cost is split by half, it is because that title has been validated in the mode analysed in that table and in other public mode.

- If the cost is zero, it means that the title has been used for a change of vehicle within the same mode (for example, between two urban bus lines).

The results will be displayed in order, starting with the base scenario and following with the alternatives 1.1, 1.2, 2 and 3. The public modes will follow this order: urban buses, metro and tramway, interurban buses and commuter trains. The columns will show the code used by the PMoMe to identify each title, their names, the associated fare, the number of validations within that public mode, the value of this validations after applying the expansion factors (therefore, the daily use of that title in one direction) and the total costs for users.

Table 26. Fares and validations by type of title and mode in the entire network. Base scenario.

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Urban buses	1	Single ticket	1.500	15	787.626	1,181.440
	23	Other	0.900	15	2,137.371	1,923.634
	40	Bonobús	0.850	75	3,507.069	2,981.009
	40	*Bonobús **	0.000	12	299.996	0.000
	41	Bonotransbordo A	0.900	2	74.683	67.215
	42	Bonotransbordo AB	1.550	3	142.151	220.333
	46.2	Abono Transporte Mensual AB	1.458	1	51.668	75.306
	46.2	*Abono Transporte Mensual AB **	0.729	2	84.873	61.851
	46.3	Abono Transporte Mensual ABC	1.718	1	133.245	228.849
	47.1	Abono Transporte Jove Mensual A	0.956	1	37.706	36.056
	47.2	Abono Transporte Jove Mensual AB	1.239	5	347.008	429.856
	47.2	*Abono Transporte Jove Mensual AB **	0.619	1	208.454	129.111
	48	Bono Oro	0.042	5	125.816	5.242
	49	Jove	0.625	4	635.169	396.981
	99.1	Does not know/Does not answer	0.900	8	124.255	111.829
Total				150	8,697.091	7,848.713
Average fare for urban buses						**0.90**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Metro and tramway	8	Other	1.080	55	3,133.095	3,383.743
	9.1	Single ticket A	1.070	3	139.011	148.742
	9.2	Single ticket AB	2.100	10	378.832	795.548
	9.3	Single ticket ABC	2.800	2	90.687	253.923
	9.4	Single ticket ABCD	3.900	3	90.656	353.560
	11.1	Bonometro 10 viajes A	0.760	56	2,812.463	2,137.472
	11.1	*Bonometro 10 viajes A **	0.000	2	98.820	0.000
	11.2	Bonometro 10 viajes AB	1.100	227	12,530.243	13,783.267
	11.2	*Bonometro 10 viajes AB **	0.000	32	1.964.950	0.000
	11.3	Bonometro 10 viajes ABC	1.470	36	2.284.534	3,358.266
	11.3	*Bonometro 10 viajes ABC **	0.000	6	213.208	0.000
	11.4	Bonometro 10 viajes ABCD	2.100	17	1,073.219	2,253.759
	12	Gent Major	0.243	33	514.757	124.829
	13	Mobilitat Mensual	0.243	2	129.316	31.359
	14	Mobilitat Anual	0.182	2	65.669	11.943
	15.1	TUIN 1 zone	0.720	7	355.769	256.153
	15.2	TUIN 2 zones	1.040	25	1,887.190	1,962.677
	15.2	*TUIN 2 zones **	0.000	4	220.496	0.000
	15.3	TUIN 3 zones	1.400	4	133.708	187.191
	15.4	TUIN 4 zones	1.400	4	470.355	658.498
	16	Bonotransbordo A	0.900	7	577.493	519.744
	16	*Bonotransbordo A **	0.450	2	74.683	33.607
	16	*Bonotransbordo A ***	0.000	2	131.453	0.000
	17	Bonotransbordo AB	1.550	30	1,921.468	2,978.275
	17	*Bonotransbordo AB **	0.450	1	33.797	15.209
	17	*Bonotransbordo AB ***	0.000	4	324.698	0.000
	21.1	Abono Transporte Mensual A	1.125	5	236.185	265.708
	21.2	Abono Transporte Mensual AB	1.458	15	1,646.347	2,399.550
	21.2	*Abono Transporte Mensual AB **	0.729	1	148.896	108.508
	21.4	Abono Transporte Mensual ABCD	1.978	2	22.188	43.876
	22.1	Abono Transporte Jove Mensual A	0.956	6	548.344	524.353
	22.2	Abono Transporte Jove Mensual AB	1.239	12	1,076.460	1,333.464

	22.3	Abono Transporte Jove Mensual ABC	1.460	3	39.027	56.979
	22.3	Abono Transporte Jove Mensual ABC *	0.730	1	27.204	19.859
	99.2	Does not know/Does not answer	1.070	12	542.198	580.152
Total				633	35,937.418	38,580.215
Average fare for metro and tramway						**1.07**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Interurban buses	39.2	Single ticket AB	1.850	27	960.183	1,776.339
	39.3	Single ticket ABC	2.850	4	426.942	1,216.786
	39.4	Single ticket ABCD	3.750	5	353.046	1,323.924
	52	Other	1.790	18	428.808	767.566
	54	Bonotransbordo A	0.900	5	286.761	258.084
	54	Bonotransbordo A *	0.450	1	71.444	32.150
	55	Bonotransbordo AB	1.550	1	99.769	154.641
	55	Bonotransbordo AB *	0.775	1	99.769	77.321
	59.2	Abono Transporte Mensual AB	1.458	3	257.657	375.535
	59.2	Abono Transporte Mensual AB *	0.729	3	233.769	170.359
	59.3	Abono Transporte Mensual ABC	1.718	1	269.041	462.077
	59.4	Abono Transporte Mensual ABCD	1.978	1	77.693	153.638
	60.2	Abono Transporte Jove Mensual AB	1.239	1	150.400	186.308
	60.2	Abono Transporte Jove Mensual AB *	0.619	1	208.454	129.111
	60.3	Abono Transporte Jove Mensual ABC *	0.730	1	27.204	19.859
	60.4	Abono Transporte Jove Mensual ABCD	1.681	2	201.966	339.555
	67.1	Pass with 10 journeys A	1.350	2	101.124	136.517
	67.2	Pass with 10 journeys AB	1.750	15	1,176.273	2,058.478
	67.3	Pass with 10 journeys ABC	2.350	4	94.771	222.713
	67.4	Pass with 10 journeys ABCD	3.250	1	17.541	57.008
	99.3	Does not know/Does not answer	1.790	19	813.329	1,455.860
Total				116	6,355.943	11,373.827
Average fare for interurban buses						**1.79**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Commuter trains	2.1	Round-trip ticket 1 zone	1.800	1	150.400	270.720
	2.2	Round-trip ticket 2 zones	2.050	3	32.194	65.997
	2.3	Round-trip ticket 3 zones	2.650	1	5.718	15.153
	3.1	Abono mensual limitado 1 zone	0.854	4	351.258	299.887
	3.2	Abono mensual limitado 2 zones	1.105	1	105.191	116.236
	3.3	Abono mensual limitado 3 zones	1.536	5	539.182	828.318
	3.4	Abono mensual limitado 4 zones	2.029	4	389.750	790.706
	4.1	Abono mensual ilimitado 1 zone	1.224	2	242.775	297.096
	4.4	Abono mensual ilimitado 4 zones	2.448	1	60.793	148.790
	5.1	Abono estudio 1 zone	0.760	2	687.286	522.623
	5.3	Abono estudio 3 zones	1.485	1	97.101	144.195
	6.1	Bonotren 1 zone	1.200	7	500.422	600.506
	6.2	Bonotren 2 zones	1.385	6	439.719	609.011
	6.3	Bonotren 3 zones	1.855	3	333.312	618.295
	6.4	Bonotren 4 zones	2.515	3	303.478	763.247
	7.1	Tarjeta Dorada 1 zone	1.080	2	40.457	43.694
	7.3	Tarjeta Dorada 3 zones	1.590	2	39.211	62.345
	7.4	Tarjeta Dorada 4 zones	2.220	2	26.596	59.043
	24.1	Single ticket 1 zone	1.800	4	40.601	73.081

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
	24.2	Single ticket 2 zones	2.050	3	229.863	471.218
	24.3	Single ticket 3 zones	2.650	1	110.798	293.614
	24.4	Single ticket 4 zones	3.700	1	32.188	119.095
	38	Other	1.520	8	507.989	772.143
	99.4	Does not know/Does not answer	1.520	2	13.820	21.006
Total				69	5,280.100	8,006.019
Average fare for commuter trains						**1.52**

Global average fare	**1.16**

Table 27. Fares and validations by type of title and mode in the entire network. Alternative 1.1.

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Urban buses	1	Single ticket	1.500	14	785.715	1,178.573
	23	Other	0.890	15	2,137.371	1,902.261
	40	Bonobús	0.850	73	3,370.261	2,864.722
	40	*Bonobús **	0.000	12	299.996	0.000
	41	Bonotransbordo A	0.900	2	74.683	67.215
	42	Bonotransbordo AB	1.550	3	142.151	220.333
	46.2	Abono Transporte Mensual AB	1.458	1	51.668	75.306
	46.2	*Abono Transporte Mensual AB **	0.729	2	84.873	61.851
	47.1	Abono Transporte Jove Mensual A	0.956	1	37.706	36.056
	47.2	Abono Transporte Jove Mensual AB	1.239	5	347.008	429.856
	47.2	*Abono Transporte Jove Mensual AB **	0.619	1	208.454	129.111
	48	Bono Oro	0.042	5	125.816	5.242
	49	Jove	0.625	4	635.169	396.981
	99.1	Does not know/Does not answer	0.890	5	105.536	93.927
	100.2	Global Ticket AB *	0.800	2	136.808	109.446
	104.3	Full Pass ABC *	0.925	3	138.349	127.973
	104.4	Full Pass ABCD *	1.200	1	13.616	16.339
	108.4	Youth Full Pass ABCD *	1.019	1	1.911	1.947
Total				150	8,697.091	7,717.139
Average fare for urban buses						**0.89**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Metro and tramway	8	Other	1.040	53	3,030.972	3,152.210
	9.1	Single ticket A	1.500	3	139.011	208.516
	9.2	Single ticket AB	2.100	10	378.832	795.548
	9.3	Single ticket ABC	2.800	2	90.687	253.923
	9.4	Single ticket ABCD	3.900	3	90.656	353.560
	11.1	Bonometro A	0.760	56	2,812.463	2,137.472
	11.1	*Bonometro A **	0.000	2	98.820	0.000
	11.2	Bonometro AB	1.100	223	12,085.029	13,293.532
	11.2	*Bonometro AB **	0.000	32	1,964.950	0.000
	11.3	Bonometro ABC	1.470	32	1,756.193	2,581.604
	11.3	*Bonometro ABC **	0.000	6	213.208	0.000
	11.4	Bonometro ABCD	2.100	16	1,073.014	2,253.330
	12	Gent Major	0.243	33	514.757	124.829
	13	Mobilitat Mensual	0.243	2	129.316	31.359
	14	Mobilitat Anual	0.182	2	65.669	11.943
	15.1	TUIN 1 zone	0.720	7	355.769	256.153
	15.2	TUIN 2 zones	1.040	25	1,887.190	1,962.677
	15.2	*TUIN 2 zones **	0.000	4	220.496	0.000
	15.3	TUIN 3 zones	1.400	4	133.708	187.191

	15.4	TUIN 4 zones	1.400	4	470.355	658.498
	16	Bonotransbordo A	0.900	7	577.493	519.744
	16	*Bonotransbordo A **	0.450	2	74.683	33.607
	16	*Bonotransbordo A ***	0.000	2	131.453	0.000
	17	Bonotransbordo AB	1.550	30	1,921.468	2,978.275
	17	*Bonotransbordo AB **	0.450	1	33.797	15.209
	17	*Bonotransbordo AB ***	0.000	4	324.698	0.000
	21.1	Abono Transporte Mensual A	1.125	5	236.185	265.708
	21.2	Abono Transporte Mensual AB	1.458	13	1,490.061	2,171.764
	21.2	*Abono Transporte Mensual AB **	0.729	1	148.896	108.508
	21.4	Abono Transporte Mensual ABCD	1.978	2	22.188	43.876
	22.1	Abono Transporte Jove Mensual A	0.956	6	548.344	524.353
	22.2	Abono Transporte Jove Mensual AB	1.239	12	1,076.460	1,333.464
	22.3	Abono Transporte Jove Mensual ABC	1.460	3	39.027	56.979
	22.3	*Abono Transporte Jove Mensual ABC **	0.730	1	27.204	19.859
	99.2	Does not know/Does not answer	1.040	10	342.417	356.114
	101.1	Global Ticket A *	0.550	10	559.398	307.669
	101.2	Global Ticket AB *	0.800	17	618.889	495.111
	101.3	Global Ticket ABC *	1.000	2	297.995	297.995
	101.4	Global Ticket ABCD *	1.300	5	218.954	284.640
	105.1	Full Pass A *	0.600	1	111.835	67.101
	105.2	Full Pass AB *	0.738	9	641.370	473.010
	105.3	Full Pass ABC *	0.925	9	523.685	484.408
	105.4	Full Pass ABCD *	1.200	7	268.154	321.785
	109.1	Youth Full Pass A *	0.506	4	199.467	100.980
	109.3	Youth Full Pass ABC *	0.788	1	97.101	76.467
	109.4	Youth Full Pass ABCD *	1.019	1	95.438	97.227
Total				684	38,137.754	39,696.202
Average fare for metro and tramway						**1.06**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Interurban buses	39.2	Single ticket AB	1.850	27	960.183	1,776.339
	39.3	Single ticket ABC	2.850	4	426.942	1,216.786
	39.4	Single ticket ABCD	3.750	5	353.046	1,323.924
	52	Other	1.790	18	428.808	767.566
	54	Bonotransbordo A	0.900	5	286.761	258.084
	54	*Bonotransbordo A **	0.450	1	71.444	32.150
	55	Bonotransbordo AB	1.550	1	99.769	154.641
	55	*Bonotransbordo AB **	0.775	1	99.769	77.321
	59.2	Abono Transporte Mensual AB	1.458	3	257.657	375.535
	59.2	*Abono Transporte Mensual AB **	0.729	3	233.769	170.359
	59.3	Abono Transporte Mensual ABC	1.718	1	269.041	462.077
	59.4	Abono Transporte Mensual ABCD	1.978	1	77.693	153.638
	60.2	Abono Transporte Jove Mensual AB	1.239	1	150.400	186.308
	60.2	*Abono Transporte Jove Mensual AB **	0.619	1	208.454	129.111
	60.3	*Abono Transporte Jove Mensual ABC **	0.730	1	27.204	19.859
	60.4	Abono Transporte Jove Mensual ABCD	1.681	2	201.966	339.555
	60.4	*Abono Transporte Jove Mensual ABCD **	0.841	0	0.000	0.000
	67.1	Pass with10 journeys A	1.350	2	101.124	136.517
	67.2	Pass with 10 journeys AB	1.750	15	1,176.273	2,058.478
	67.3	Pass with 10 journeys ABC	2.350	4	94.771	222.713
	67.4	Pass with 10 journeys ABCD	3.250	1	17.541	57.008
	99.3	Does not know/Does not answer	1.790	19	813.329	1,455.860
Total				116	6,355.943	11,373.827
Average fare for interurban buses						**1.79**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Commuter trains	2.2	Round-trip ticket 2 zones	2.050	3	32.194	65.997
	2.3	Round-trip ticket 3 zones	2.650	1	5.718	15.153
	2.4	Round-trip ticket 4 zones	3.700	0	0.000	0.000
	3.1	Abono mensual limitado 1 zone	0.854	2	145.954	124.608
	3.2	Abono mensual limitado 2 zones	1.105	1	105.191	116.236
	3.3	Abono mensual limitado 3 zones	1.536	3	272.691	418.922
	3.4	Abono mensual limitado 4 zones	2.029	3	330.809	671.128
	4.1	Abono mensual ilimitado 1 zone	1.224	1	179.960	220.226
	4.4	Abono mensual ilimitado 4 zones	2.448	1	60.793	148.790
	5.1	Abono estudio 1 zone	0.760	2	687.286	522.623
	6.1	Bonotren 1 zone	1.200	6	383.282	459.938
	6.2	Bonotren 2 zones	1.385	4	305.476	423.085
	6.3	Bonotren 3 zones	1.855	1	35.318	65.515
	6.4	Bonotren 4 zones	2.515	3	303.478	763.247
	7.1	Tarjeta Dorada 1 zone	1.080	2	40.457	43.694
	7.3	Tarjeta Dorada 3 zones	1.590	2	39.211	62.345
	24.1	Single ticket 1 zone	1.800	4	40.601	73.081
	24.2	Single ticket 2 zones	2.050	2	161.459	330.990
	24.3	Single ticket 3 zones	2.650	1	110.798	293.614
	24.4	Single ticket 4 zones	3.700	1	32.188	119.095
	38	Other	1.160	6	308.208	357.521
	103.1	Global Ticket A *	0.550	10	559.398	307.669
	103.2	Global Ticket AB *	0.800	19	755.697	604.557
	103.3	Global Ticket ABC *	1.000	2	0.000	0.000
	103.4	Global Ticket ABCD *	1.300	5	218.954	284.640
	107.1	Full Pass A *	0.600	1	111.835	67.101
	107.2	Full Pass AB *	0.738	9	641.370	473.010
	107.3	Full Pass ABC *	0.925	12	504.816	466.955
	107.4	Full Pass ABCD	2.400	1	58.941	141.460
	107.4	Full Pass ABCD *	1.200	8	281.770	338.124
	111.1	Youth Full Pass A *	0.506	3	242.649	122.841
	111.3	Youth Full Pass ABC *	0.788	1	97.101	76.467
	111.4	Youth Full Pass ABCD *	1.019	2	97.349	99.174
Total				122	7,150.948	8,277.805
Average fare for commuter trains						**1.16**

Global average fare	**1.13**

Table 28. Fares and validations by type of title and mode in the entire network. Alternative 1.2.

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Urban buses	1	Single ticket	1.500	14	785.715	1,178.573
	23	Other	0.890	15	2,137.371	1,902.261
	40	Bonobús	0.850	73	3,370.261	2,861.070
	40	*Bonobús **	0.000	12	299.996	0.000
	41	Bonotransbordo A	0.900	2	74.683	67.215
	42	Bonotransbordo AB	1.550	3	142.151	220.333
	46.2	Abono Transporte Mensual AB	1.458	1	51.668	75.306
	46.2	*Abono Transporte Mensual AB **	0.729	2	84.873	61.851
	47.1	Abono Transporte Jove Mensual A	0.956	1	37.706	36.056
	47.2	Abono Transporte Jove Mensual AB	1.239	5	347.008	429.856
	47.2	*Abono Transporte Jove Mensual AB **	0.619	1	208.454	129.111
	48	Bono Oro	0.042	5	125.816	5.242
	49	Jove	0.625	4	635.169	396.981
	99.1	Does not know/Does not answer	0.890	5	105.536	93.927
	100.2	Global Ticket AB *	0.800	2	136.808	109.446
	104.3	Full Pass ABC *	0.925	3	138.349	127.973
	104.4	Full Pass ABCD *	1.200	1	13.616	16.339
	108.4	Youth Full Pass ABCD *	1.019	1	1.911	1.947
Total				150	8,692.796	7,713.487
Average fare for urban buses						**0.89**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Metro and tramway	8	Other	1.000	52	2,807.960	2,807.960
	9.1	Single ticket A	1.500	3	139.011	208.516
	9.2	Single ticket AB	2.100	10	378.832	795.548
	9.3	Single ticket ABC	2.800	2	90.687	253.923
	9.4	Single ticket ABCD	3.900	3	90.656	353.560
	11.1	Bonometro A	0.760	56	2,812.463	2,137.472
	11.1	*Bonometro A **	0.000	2	98.820	0.000
	11.2	Bonometro AB	1.100	224	12,100.177	13,310.195
	11.2	*Bonometro AB **	0.000	32	1,964.950	0.000
	11.3	Bonometro ABC	1.470	32	1,756.193	2,581.604
	11.3	*Bonometro ABC **	0.000	6	213.208	0.000
	11.4	Bonometro ABCD	2.100	16	1,073.014	2,253.330
	12	Gent Major	0.243	33	514.757	124.829
	13	Mobilitat Mensual	0.243	2	129.316	31.359
	14	Mobilitat Anual	0.182	2	65.669	11.943
	15.1	TUIN 1 zone	0.720	7	355.769	256.153
	15.2	TUIN 2 zones	1.040	25	1,887.190	1,962.677
	15.2	*TUIN 2 zones **	0.000	4	220.496	0.000
	15.3	TUIN 3 zones	1.400	4	133.708	187.191
	15.4	TUIN 4 zones	1.400	4	470.355	658.498
	16	Bonotransbordo A	0.900	7	577.493	519.744
	16	*Bonotransbordo A **	0.450	2	74.683	33.607
	16	*Bonotransbordo A ***	0.000	2	131.453	0.000
	17	Bonotransbordo AB	1.550	30	1,921.468	2,978.275
	17	*Bonotransbordo AB **	0.450	1	33.797	15.209
	17	*Bonotransbordo AB ***	0.000	4	324.698	0.000
	21.1	*Abono Transporte Mensual A **	1.125	5	236.185	265.708
	21.2	*Abono Transporte Mensual AB **	1.458	13	1,490.061	2,171.764
	21.2	Abono Transporte Mensual ABC	0.729	1	148.896	108.508

	21.4	*Abono Transporte Mensual ABCD **	1.978	2	53.807	106.403
	22.1	*Abono Transporte Jove Mensual A **	0.956	6	548.344	524.353
	22.2	*Abono Transporte Jove Mensual AB **	1.239	12	1,076.460	1,333.464
	22.3	*Abono Transporte Jove Mensual ABC **	1.460	3	39.027	56.979
	22.3	Abono Transporte Jove Mensual ABCD	0.730	1	27.204	19.859
	99.2	Global Ticket A	1.000	10	342.417	342.417
	101.1	Global Ticket AB	0.550	28	1,575.189	866.354
	101.2	Global Ticket ABC	0.800	78	2,786.270	2,229.016
	101.3	Global Ticket ABCD	1.000	12	627.997	627.997
	101.4	Full Pass A	1.300	8	316.790	411.827
	105.1	Full Pass AB	0.600	5	250.379	150.227
	105.2	Full Pass ABC	0.738	34	1,937.087	1,428.602
	105.3	Full Pass ABCD	0.925	14	614.608	568.512
	105.4	Youth Full Pass A	1.200	13	573.303	687.963
	109.1	Youth Full Pass AB	0.506	5	393.668	199.295
	109.3	Youth Full Pass ABCD	0.788	1	97.101	76.467
	109.4	Youth Full Pass ABCD *	1.019	1	95.438	97.227
	113.1	Reduced Full Pass A *	0.450	2	14.752	6.639
	113.2	Reduced Full Pass AB *	0.550	24	286.929	157.811
	113.3	Reduced Full Pass ABC *	0.694	4	28.542	19.801
Total				847	43,927.277	43,938.788
Average fare for metro and tramway						**1.00**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Interurban buses	39.2	Single ticket AB	1.850	27	960.183	1,776.339
	39.3	Single ticket ABC	2.850	4	426.942	1,216.786
	39.4	Single ticket ABCD	3.750	5	353.046	1,323.924
	52	Other	1.790	18	428.808	767.566
	54	Bonotransbordo A	0.900	5	286.761	258.084
	54	*Bonotransbordo A **	0.450	1	71.444	32.150
	55	Bonotransbordo AB	1.550	1	99.769	154.641
	55	*Bonotransbordo AB **	0.775	1	99.769	77.321
	59.2	Abono Transporte Mensual AB	1.458	3	257.657	375.535
	59.2	*Abono Transporte Mensual AB **	0.729	3	233.769	170.359
	59.3	Abono Transporte Mensual ABC	1.718	1	269.041	462.077
	59.4	Abono Transporte Mensual ABCD	1.978	1	77.693	153.638
	60.2	Abono Transporte Jove Mensual AB	1.239	1	150.400	186.308
	60.2	*Abono Transporte Jove Mensual AB **	0.619	1	208.454	129.111
	60.3	*Abono Transporte Jove Mensual ABC **	0.730	1	27.204	19.859
	60.4	Abono Transporte Jove Mensual ABCD	1.681	2	236.264	397.220
	60.4	*Abono Transporte Jove Mensual ABCD **	0.841	0	0.000	0.000
	67.1	Pass with 10 journeys A	1.350	2	101.124	136.517
	67.2	Pass with 10 journeys AB	1.750	15	1,176.273	2,058.478
	67.3	Pass with 10 journeys ABC	2.350	4	94.771	222.713
	67.4	Pass with 10 journeys ABCD	3.250	1	17.541	57.008
	99.3	Does not know/Does not answer	1.790	19	813.329	1,455.860
Total				116	6,428.877	11,559.304
Average fare for interurban buses						**1.78**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Commuter trains	2.2	Round-trip ticket 2 zones	2.050	3	21.804	44.699
	2.3	Round-trip ticket 3 zones	2.650	1	5.718	15.153
	3.1	Abono mensual limitado 1 zone	0.854	2	145.954	124.608
	3.2	Abono mensual limitado 2 zones	1.105	1	105.191	116.236
	3.3	Abono mensual limitado 3 zones	1.536	3	272.691	418.922
	3.4	Abono mensual limitado 4 zones	2.029	3	330.809	671.128
	4.1	Abono mensual ilimitado 1 zone	1.224	1	179.960	220.226
	4.4	Abono mensual ilimitado 4 zones	2.448	1	60.793	148.790
	5.1	Abono estudio 1 zone	0.760	2	687.286	522.623
	6.1	Bonotren 1 zone	1.200	6	383.282	459.938
	6.2	Bonotren 2 zones	1.385	4	430.095	595.681
	6.3	Bonotren 3 zones	1.855	1	35.318	65.515
	6.4	Bonotren 4 zones	2.515	3	303.478	763.247
	7.1	Tarjeta Dorada 1 zone	1.080	2	40.457	43.694
	7.3	Tarjeta Dorada 3 zones	1.590	2	39.211	62.345
	24.1	Single ticket 1 zone	1.800	4	40.601	73.081
	24.2	Single ticket 2 zones	2.050	2	161.459	330.990
	24.3	Single ticket 3 zones	2.650	1	110.798	293.614
	24.4	Single ticket 4 zones	3.700	1	32.188	119.095
	38	Other	1.000	6	308.208	308.208
	103.1	Global Ticket A *	0.550	28	1,575.189	866.354
	103.2	Global Ticket AB *	0.800	80	2,923.078	2,338.462
	103.3	Global Ticket ABC *	1.000	12	330.003	330.003
	103.4	Global Ticket ABCD *	1.300	8	316.790	411.827
	107.1	Full Pass A *	0.600	5	250.379	150.227
	107.2	Full Pass AB	1.475	14	619.728	914.099
	107.2	Full Pass AB *	0.738	34	1,937.087	1,428.602
	107.3	Full Pass ABC *	0.925	17	595.739	551.059
	107.4	Full Pass ABCD	2.400	1	58.941	141.460
	107.4	Full Pass ABCD *	1.200	14	586.918	704.302
	111.1	Youth Full Pass A *	0.506	4	436.850	221.155
	111.3	Youth Full Pass ABC *	0.788	1	97.101	76.467
	111.4	Youth Full Pass ABCD *	1.019	2	97.349	99.174
	115.1	Reduced Full Pass A *	0.450	2	14.752	6.639
	115.2	Reduced Full Pass AB *	0.550	24	286.929	157.811
	115.3	Reduced Full Pass ABC *	0.694	4	28.542	19.801
Total				299	13,850.674	13,815.234
Average fare for commuter trains						**1.08**

Global average fare	**1.08**

Table 29. Fares and validations by type of title and mode in the entire network. Alternative 2.

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Urban buses	1	Single ticket	1.500	15	787.626	1,181.440
	48	Bono Oro	0.042	5	125.816	5.242
	100.1	30 Days A	0.875	2	59.271	51.862
	100.2	30 Days AB	1.125	2	56.535	63.602
	100.2	*30 Days AB **	0.563	1	45.300	25.481
	100.3	30 Days ABC	1.500	4	100.560	150.840
	100.3	*30 Days ABC **	0.750	1	133.245	99.934
	100.4	30 Days ABCD	2.000	2	110.889	221.778
	104.1	Youth 30 Days A	0.744	1	37.706	28.053
	104.2	Youth 30 Days AB	0.956	6	425.689	406.959
	104.2	*Youth 30 Days AB **	0.478	1	208.454	99.641
	112.1	Pass 10 A	0.900	35	1,262.016	1,135.814
	112.1	*Pass 10 A ***	0.000	4	10.307	0.000
	112.2	Pass 10 AB	1.200	52	3,377.988	4,053.586
	112.2	*Pass 10 AB ***	0.000	6	589.331	0.000
	112.3	Pass 10 ABC	1.550	8	580.539	899.836
	112.4	Pass 10 ABCD	2.100	6	102.651	215.568
Total				151	8,013.925	8,639.637
Average fare for urban buses						**1.02**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Metro and tramway	9.1	Single ticket A	1.070	3	139.011	148.742
	9.2	Single ticket AB	2.100	9	309.679	650.326
	9.3	Single ticket ABC	2.800	2	90.687	253.923
	9.4	Single ticket ABCD	3.900	3	90.656	353.560
	12	Gent Major	0.243	33	514.757	124.829
	13	Mobilitat Mensual	0.243	1	31.778	7.706
	14	Mobilitat Anual	0.182	2	65.669	11.943
	101.1	30 Days A	0.875	4	193.420	169.242
	101.1	*30 Days A **	0.438	2	156.285	68.375
	101.2	30 Days AB	1.125	13	1,627.398	1,830.823
	101.2	*30 Days AB **	0.563	1	148.896	83.754
	101.3	30 Days ABC	1.500	7	154.347	231.521
	101.4	30 Days ABCD	2.000	4	43.677	87.354
	101.4	*30 Days ABCD **	1.000	1	58.941	58.941
	105.1	Youth 30 Days A	0.744	6	548.344	407.968
	105.2	Youth 30 Days AB	0.956	9	727.266	695.266
	105.3	Youth 30 Days ABC	1.275	3	39.027	49.759
	105.3	*Youth 30 Days ABC **	0.638	1	27.204	17.342
	109.2	Reduced 30 Days AB	0.844	1	2.487	2.099
	113.1	Pass 10 A	0.900	74	4,196.534	3,776.880
	113.1	*Pass 10 A **	0.450	1	51.923	23.365
	113.1	*Pass 10 A ***	0.000	10	1.114.033	0.000
	113.2	Pass 10 AB	1.200	254	13.992.890	16.791.468
	113.2	*Pass 10 AB **	0.600	10	343.340	206.004
	113.2	*Pass 10 AB ***	0.000	84	5,232.379	0.000
	113.3	Pass 10 ABC	1.550	48	2,366.402	3,667.923
	113.3	*Pass 10 ABC **	0.775	4	551.395	427.331
	113.3	*Pass 10 ABC ***	0.000	16	531.958	0.000

	113.4	Pass 10 ABCD	2.100	28	1,916.386	4,024.410
	113.4	*Pass 10 ABCD ***	0.000	4	200.875	0.000
Total				638	35,467.644	34,170.856
Average fare for metro and tramway						**0.96**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Interurban buses	39.2	Single ticket AB	1.850	27	960.183	1,776.339
	39.3	Single ticket ABC	2.850	3	416.600	1,187.310
	39.4	Single ticket ABCD	3.750	4	316.132	1,185.494
	102.2	30 Days AB	1.125	5	304.428	342.482
	102.2	*30 Days AB **	0.563	2	194.196	109.235
	102.3	30 Days ABC	1.500	5	313.743	470.615
	102.4	30 Days ABCD	2.000	4	124.061	248.121
	106.2	Youth 30 Days AB	0.956	1	150.400	143.782
	106.2	*Youth 30 Days AB **	0.478	1	208.454	99.641
	106.3	*Youth 30 Days ABC **	0.638	1	27.204	17.342
	106.4	Youth 30 Days ABCD	1.700	2	201.966	343.342
	114.1	Pass 10 A	0.900	8	389.995	350.996
	114.2	Pass 10 AB	1.200	29	1,894.172	2,273.006
	114.2	*Pass 10 AB **	0.600	9	310.436	186.261
	114.3	Pass 10 ABC	1.550	10	277.747	430.507
	114.3	*Pass 10 ABC **	0.775	2	98.080	76.012
	114.4	Pass 10 ABCD	2.100	15	420.590	883.239
	114.4	*Pass 10 ABCD **	1.050	4	105.402	110.672
Total				132	6,713.788	10,234.397
Average fare for interurban buses						**1.52**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Commuter trains	24.1	Single ticket 1 zone	1.800	4	40.601	73.081
	24.2	Single ticket 2 zones	2.050	3	229.863	471.218
	24.3	Single ticket 3 zones	2.650	1	110.798	293.614
	24.4	Single ticket 4 zones	3.700	1	32.188	119.095
	103.1	30 Days A	0.875	5	481.565	421.370
	103.1	*30 Days A **	0.438	2	156.285	68.375
	103.2	30 Days AB	1.125	1	105.191	118.340
	103.3	30 Days ABC	1.500	7	262.626	393.940
	103.3	*30 Days ABC **	0.750	1	133.245	99.934
	103.4	30 Days ABCD	2.000	4	356.712	713.424
	103.4	*30 Days ABCD **	1.000	1	0.000	0.000
	107.1	Youth 30 Days A	0.744	2	687.286	511.341
	111.3	Reduced 30 Days ABC	1.125	1	11.320	12.735
	111.4	Reduced 30 Days ABCD	1.500	2	2.116	3.173
	115.1	Pass 10 A	0.900	12	642.946	578.652
	115.1	*Pass 10 A **	0.450	3	310.722	139.825
	115.1	*Pass 10 A ***	0.000	2	176.138	0.000
	115.2	Pass 10 AB	1.200	13	695.559	834.670
	115.2	*Pass 10 AB **	0.600	2	134.243	80.546
	115.3	Pass 10 ABC	1.550	15	1,126.842	1,746.605
	115.3	*Pass 10 ABC **	0.775	6	469.313	363.717
	115.4	Pass 10 ABCD	2.100	9	482.901	1,014.093
	115.4	*Pass 10 ABCD **	1.050	1	13.616	14.296
Total				98	6,662.076	8,072.044
Average fare for commuter trains						**1.21**

Global average fare	**1.08**

Table 30. Fares and validations by type of title and mode in the entire network. Alternative 3.

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Urban buses	48	Bono Oro	0.042	3	120.513	5.021
	100.1	Flat fare A	0.900	9	607.644	546.880
	100.1	Flat fare A *	0.450	3	290.783	130.852
	100.2	Flat fare AB	1.100	113	6,004.867	6,605.354
	100.2	Flat fare AB *	0.550	30	1,552.619	853.940
	100.3	Flat fare ABC	1.450	14	1,037.308	1,504.097
	100.3	Flat fare ABC *	0.725	10	994.567	721.061
	100.4	Flat fare ABCD	1.900	7	135.800	258.020
	100.4	Flat fare ABCD *	0.950	3	71.059	67.506
	104.1	Youth flat fare A	0.770	0	0.000	0.000
	104.1	Youth flat fare A *	0.385	0	0.000	0.000
	104.2	Youth flat fare AB	0.940	2	1,067.352	1,003.311
	108.1	Reduced flat fare A	0.680	6	114.313	77.733
	108.2	Reduced flat fare AB	0.820	8	14.135	11.591
	108.2	Reduced flat fare AB *	0.410	2	3.012	1.235
	108.4	Reduced flat fare ABCD	1.500	1	1.911	2.867
	108.4	Reduced flat fare ABCD *	0.750	1	1.911	1.434
Total				212	12,017.794	11,790.902
Average fare for urban buses						**0.90**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Metro and tramway	12	Gent Major	0.243	30	509.164	123.472
	101.1	Flat fare A	0.900	97	5,696.590	5,126.931
	101.1	Flat fare A *	0.450	9	831.918	374.363
	101.2	Flat fare AB	1.100	363	21,889.903	24,078.894
	101.2	Flat fare AB *	0.550	23	969.757	533.366
	101.3	Flat fare ABC	1.450	74	3,837.299	5,564.084
	101.3	Flat fare ABC *	0.725	15	1,667.961	1,209.272
	101.4	Flat fare ABCD	1.900	48	2,776.282	5,274.936
	101.4	Flat fare ABCD *	0.950	3	145.016	137.765
	105.1	Youth flat fare A	0.770	4	825.698	635.787
	105.2	Youth flat fare AB	0.940	8	481.031	452.169
	105.3	Youth flat fare ABC	1.230	1	89.204	109.721
	105.4	Youth flat fare ABCD	1.620	1	367.407	595.199
	109.1	Reduced flat fare A	0.680	7	25.342	17.233
	109.2	Reduced flat fare AB	0.820	28	132.447	108.606
	109.3	Reduced flat fare ABC	1.130	5	15.408	17.410
	109.4	Reduced flat fare ABCD	1.500	4	2.277	3.416
	109.4	Reduced flat fare ABCD *	0.750	1	0.204	0.153
Total				721	40,262.910	44,362.779
Average fare for metro and tramway						**1.06**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Interurban buses	102.1	Flat fare A	0.900	5	191.422	172.280
	102.2	Flat fare AB	1.100	72	3,975.484	4,373.032
	102.2	Flat fare AB *	0.550	25	1,594.079	876.743
	102.3	Flat fare ABC	1.450	27	854.841	1,239.520
	102.3	Flat fare ABC *	0.725	5	144.450	104.726
	102.4	Flat fare ABCD	1.900	22	1,063.559	2,020.761
	102.4	Flat fare ABCD *	0.950	4	143.518	136.342
	106.2	Youth flat fare AB	0.940	2	289.235	271.881
	106.3	Youth flat fare ABC	1.230	1	404.898	498.024
	110.2	Reduced flat fare AB	0.820	9	47.701	39.114
	110.2	Reduced flat fare AB *	0.410	2	3.012	1.235
	110.4	Reduced flat fare ABCD	1.500	4	62.599	93.899
Total				178	8,774.796	9,827.557
Average fare for interurban buses						**1.10**

	Code	Title	Fare (€)	Validations	Expanded validations	Fare x Exp. Val.
Commuter trains	103.1	Flat fare A	0.900	24	2,010.620	1,809.558
	103.1	Flat fare A *	0.450	7	622.024	279.911
	103.2	Flat fare AB	1.100	18	1,232.896	1,356.185
	103.2	Flat fare AB *	0.550	3	202.647	111.456
	103.3	Flat fare ABC	1.450	24	1,519.153	2,202.772
	103.3	Flat fare ABC *	0.725	8	368.077	266.856
	103.4	Flat fare ABCD	1.900	14	870.570	1,654.083
	103.4	Flat fare ABCD *	0.950	2	13.616	12.935
	111.1	Reduced flat fare A	0.680	1	19.653	13.364
	111.3	Reduced flat fare ABC	1.130	1	27.890	31.516
	111.4	Reduced flat fare ABCD	1.500	2	2.116	3.173
	111.4	Reduced flat fare ABCD *	0.750	2	2.116	1.587
Total				106	6,891.377	7743.396
Average fare for commuter trains						**1.09**

Global average fare	**1.05**